JADS JT&E-TR-99-020

JADS JT&E

A Test Planning Methodology From Concept Development Through Test Execution

by: John Reeves, SAIC, and
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November 1999

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Joint Advanced Distributed Simulation
Joint Test Force
2050A 2nd St. SE
Kirtland Air Force Base, New Mexico 87117-5522

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	30 November 1999	1 Oct 94 - 31 Mar 00

4. TITLE AND SUBTITLE

A Test Planning Methodology – From Concept Development Through Test Execution

5. FUNDING NUMBERS

N/A

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

JOINT ADVANCED DISTRIBUTED SIMULATION (JADS) JOINT TEST FORCE(JTF)
2050A Second Street SE
Kirtland AFB NM 87117-5522

8. PERFORMING ORGANIZATION REPORT NUMBER

JADS JT&E-TR-99-020

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

OUSD(A&T)
DEPUTY DIRECTOR,
DEVELOPMENTAL TEST & EVAL
RM 3D1080
3110 DEFENSE PENTAGON
WASHINGTON DC 20301-3110

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

N/A

11. SUPPLEMENTARY NOTES: Before 1 March 2000 this report can be obtained from JADS JTF, 2050A 2nd St. SE, KAFB NM 87117-5522; after 1 March 2000 you may obtain the report from either HQ AFOTEC/HO, 8500 Gibson Blvd SE, KAFB NM 87117-5558, or SAIC Technical Library, 2001 North Beauregard St. Suite 800, Alexandria, Virginia 22311.

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
DISTRIBUTION A - APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.	DISTRIBUTION A UNLIMITED

13. ABSTRACT *(Maximum 200 Words)*

The Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation was chartered by the Deputy Director, Test, Systems Engineering, and Evaluation (Test and Evaluation), Office of the Under Secretary of Defense (Acquisition and Technology) in October 1994 to investigate the utility of advanced distributed simulation (ADS) technologies for support of development test and evaluation and operational test and evaluation. This special report outlines the steps in planning and implementing ADS-based testing. The methodology is divided into two parts: an ADS-inclusive test concept development methodology and an ADS-based test planning and implementation methodology. The objective of the test concept development methodology is to determine whether ADS-based testing is either required or desired. If the decision is made to implement ADS-based testing, then the ADS-based test planning and implementation methodology should be followed.

14. SUBJECT TERMS	15. NUMBER OF PAGES
	61
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

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1.0 Introduction

This special report outlines the steps in planning and implementing advanced distributed simulation (ADS)-based testing. The methodology is divided into two parts: an ADS-inclusive test concept development methodology and an ADS-based test planning and implementation methodology.

The objective of the test concept development methodology is to determine whether ADS-based testing is either required (because conventional testing cannot fully represent the operational environment) or desired (because there are benefits from ADS-based testing, such as cost or time savings). If the decision is made that a conventional (i.e., nondistributed) testing approach will suffice, traditional testing methodologies are used, and the section on the ADS-based test planning and implementation methodology does not apply.

If the decision is made to implement ADS-based testing, the ADS-based test planning and implementation methodology should be followed. This methodology tailors the steps given in the Defense Modeling and Simulation Office (DMSO) High Level Architecture (HLA) Federation Development and Execution Process (FEDEP) model [Ref. 1] to test and evaluation (T&E) applications.

The processes are intended to serve as checklists and "how to" guides. The intent is to provide a logical framework for assessing potential uses of ADS within a given program and to offer guidelines for ADS planning activities once a decision to use ADS is made.

Linking comes with certain costs. There is usually some degradation of data when they are shipped around, and there are the dollar and time costs associated with creating a linked environment. Because of the costs, from a tester's perspective, there have to be reasons to link. The most compelling reason for using ADS in support of testing is the complexity of the test environment. Complex environments with many players and many interactions are too expensive to represent in the open air test arena. (The complex environments may also be too expensive to represent in newly built stand-alone models.) When a test environment encompasses many interactions with human decision making involved, models tend to have serious credibility problems. If a system under test requires a highly complex, dynamic, human-in-the-loop environment, there is a good chance that ADS is a technology which can benefit the test program.

This report offers a methodology to incorporate ADS as a factor in test concept development and detailed planning. The costs and the benefits associated with the use of ADS are always very program specific. Test planners will have to look at the details of their particular program to see potential applications, costs, and benefits. One cautionary note about costing should be borne in mind. The benefits of better testing may be reflected in better products and more efficient production. Cost benefit analyses should take a program-level perspective and not be limited exclusively to test costs.

2.0 ADS-Inclusive Test Concept Development Methodology

The methodology described in this paper uses an example which is couched in terms of operational test and evaluation (OT&E). But, as OT&E moves left on the acquisition timeline and as new systems demand ever more complex test environments, the process is applicable to developmental test and evaluation (DT&E) as well.

Historically, T&E planners have had to live with severe test asset and cost limitations. As a result, the tendency during test concept development has been to analyze the operating environment from the bottom up. Typically, the process involved identifying the set of players in the operating environment that has direct interaction with the system under test and culling that group down to a minimum set. The historical approach resulted in a consistent collection of test limitations that are found in test report after test report, e.g., insufficient numbers and types of targets; insufficient numbers and types of friendly players; and inadequate representation of command, control, communications, intelligence, surveillance, and reconnaissance assets on friendly and opposing sides.

The advantage, at the cost of test limitations, of the historical approach to test concept development and planning was that uncontrolled variables were kept to a minimum, and cause and effect relationships were relatively straightforward. This was not a trivial advantage, but it was an advantage for the analysts, not the system under test (SUT) users. In combat operations the users sometimes found that factors not included in testing had significant bearing on the ability of a system to do its intended job.

It is a plausible working assumption that ADS can technically support representation of the military operating environment at the campaign or theater level. If ADS is included in the test planning tool kit from the outset, it is possible to begin the test concept development process at the top rather than the bottom. (The "top" may not be at theater level; it is established by the relevant operational task or tasks.) The methodology described in this paper is a top-level methodology. It is an approach which is compatible with the "strategy to task" or "mission level evaluation" philosophy. It is also a methodology for test concept development which incorporates the consideration of ADS -- it is not an ADS planning methodology. This methodology is designed to provide insights on whether to use ADS and where in a test program the use might fit.

The advantage of a top-down approach to test concept development is that the whole gamut of interactions is available for consideration even if many of those interactions are assessed as irrelevant and excluded from the final concept. The top-down approach doesn't require that every possible interaction be included in the test, but it does require an item by item assessment of each interaction. Decisions to exclude interactions are conscious decisions not default decisions as a function of a bottom-up approach.

Mission- or task-level evaluation is explicitly a top-down approach. The top level, for test planning purposes, may be much lower than campaign or theater. Just how high the top level is,

is a function of the task being evaluated. Some systems may have little or no interaction beyond a unit boundary, and others may interact closely with the theater and campaign levels. In the case of DT&E, it is necessary to substitute "specification sets" for "tasks." The substitution should not be difficult. While there may be evolutionary changes as a program evolves, the operational tasks expected of a new system are known as a result of mission needs analysis and serve as the basis for initial requirements development. It shouldn't be hard to map certain system specifications to a specific task. The methodology, as described, should be useful for much DT&E. The player sets in DT&E scenarios might be smaller relative to the OT&E cases.

NOTE: A top-down approach won't help much if it is implemented with a mind set fixed on historical limitations. It's necessary for the test planners to understand that ADS provides opportunities which weren't previously feasible.

In order to lend structure to the methodology, a SUT has been assumed which is a hypothetical air-ground attack aircraft. Please bear in mind that this is just an example of a process. Some of the terminology may be dated or inaccurate, but the logic for the process should hold up. The reader should have little difficulty tailoring the steps of the process to update the terminology or to apply them to other kinds of systems. The logic flow for the initial elements of the concept development methodology is shown in Figure 1.

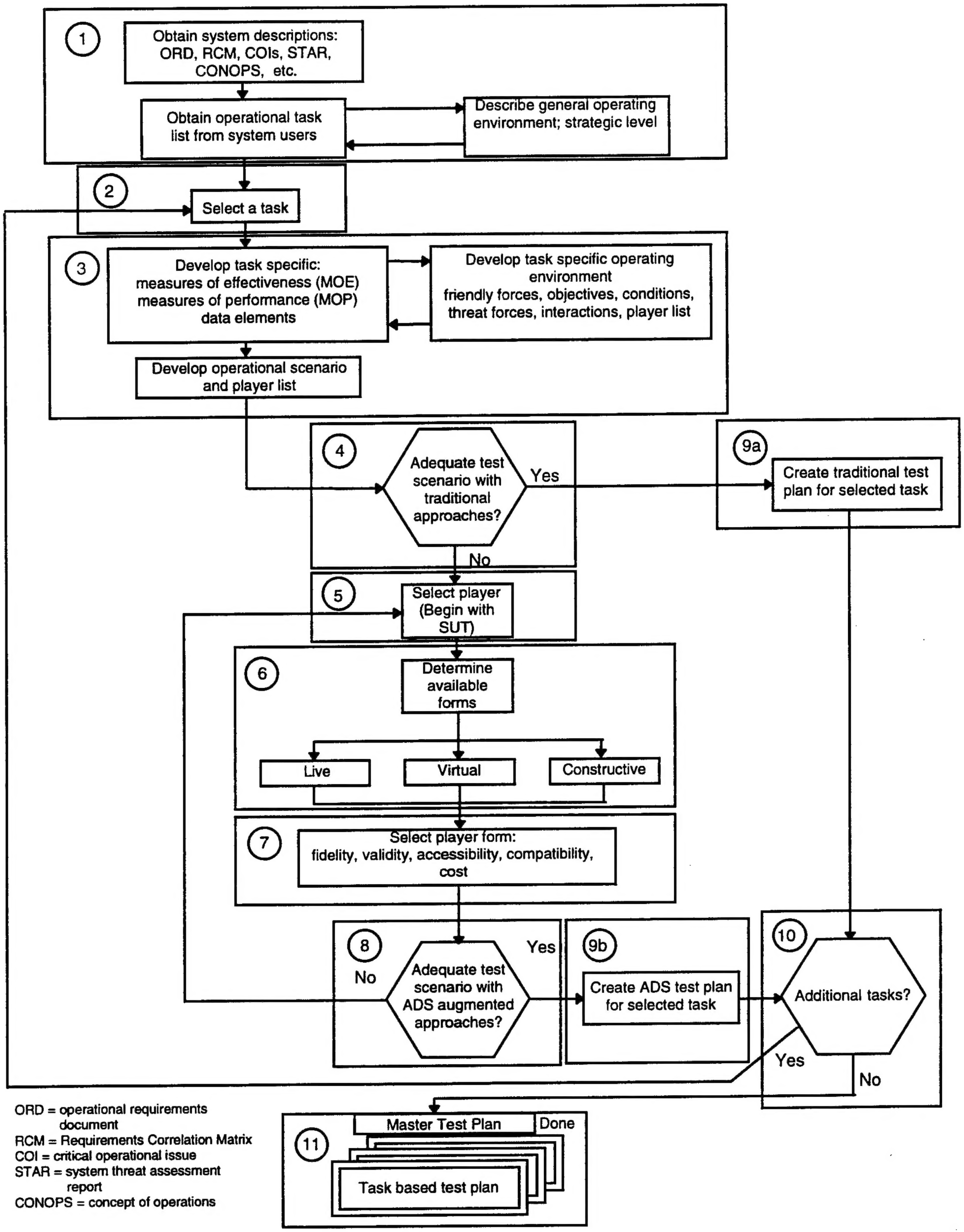


Figure 1. Logic Flow for Initial Elements of the Planning Methodology

2.1 Step 1. Understanding the System Under Test

Step 1 requires the test planners to research the acquisition documentation to gain a thorough understanding of the SUT and its intended operating environment. This understanding incorporates the operational tasks the system is designed to perform, the critical system parameters, the system and operational requirements, the concept of operations, the logistical support concept, and the top level or general operating environment. One piece of the understanding deals with the technical or specification aspects of the system. The other piece deals with the interactions between the technical characteristics of the system and the world it operates in from a strategic perspective -- the friendly and supporting forces, the natural environment, and the threats posed by the enemy. In the case of a hypothetical close air support (CAS) aircraft, the cast of potential players from a theater perspective is pretty extensive.

- Joint force headquarters
- Tactical air operations center (TAOC)
  - Air task orders
    - Fragmentary orders
- Wing operations centers (WOCs)
- Tactical operations centers (corps, division, brigade, etc.)
- Theater air defense structures
  - Air defense units
  - Control centers
    - Safe passage procedures
- Tactical air control parties
- Forward air control posts
- Airborne battlefield command and control centers (ABCCCs)
- Forward air controllers-air (FAC-A)
- Forward observers (FO)
- Air and naval gunfire liaison companies (ANGLICOs)
- Direct/indirect support units (suppressive fires)
- Logistical support agencies/units
  - Munitions
  - Consumables
- Air support assets
  - Combat Air Patrol
  - Escort
  - Suppression
  - Refueling
  - Combat search and rescue
- Airborne Warning And Control System (AWACS)
- Joint Surveillance Target Attack Radar System (Joint STARS)
- Airborne laser (ABL)

- Rivet Joint, Guardrail, and other stuff
- Allied forces
- Threats
  - Airborne interceptors
  - Surface-to-air missiles (SAM)
  - Anti-aircraft artillery (AAA)
  - Small arms
  - Ground forces
    - Airborne
    - Special forces
  - Naval forces
    - At sea
    - Ashore
- Targets
  - Troop units
  - Vehicles
  - Fixed targets
  - Weapon emplacements

Obviously not all the listed players play in every task the SUT is required to perform; as the task changes, the relevant players list changes.

Technical measures are straightforward and map directly to system requirements and specifications. The technical measures tend to remain constant through the range of operational tasks, although some of them may be stressed in some tasks and not in others.

Operational measures map to the ability of a system to perform its intended tasks. The environment and the player set may change significantly between tasks (e.g., day to night or interdiction to CAS). The operational measures may vary significantly from task to task.

Once the test planners have a thorough understanding of the system, its tasks, its operating environment and its interactions in that environment, they can proceed to the next step.

2.2 Step 2. Select a Task

This step involves the selection of a specific task. A complex system may be assigned many operational tasks. Some tasks may be very similar, while others may be vastly different. It is possible that similar tasks may be grouped for evaluation purposes and tested on the basis of a single task. In our hypothetical case we might choose a task of CAS in daylight and good weather with communications jamming (comjam), and a moderate threat environment.

2.3 Step 3. Develop Relevant Measures

Once a specific task is selected, the planners can develop relevant measures for the task and a task-specific operating environment. The operating environment in combination with assigned objectives and missions provides a context for the test measures and defines the cast of players. Let's assume for our illustrative case that we have measures associated with the following areas of SUT performance.

- Ability of the pilot in the CAS aircraft to communicate effectively with controlling, coordinating and supporting agencies in a comjam environment
- Survivability
- Ability to navigate to, identify, and attack the appropriate target
- Circular error probable (CEP), circular error average (CEA)
- Weapons effects

Given those kinds of measures, the relevant task player list might look something like the following.

- System under test
- Tactical air operations center
  - Air task order
    - Fragmentary order
- Wing operations center
- Corps tactical operations center (CTOC)
- Theater air defense structure
  - Control center
    - Safe passage procedure
- Airborne battlefield command and control centers
- Airborne forward air controller (FAC)
- Forward observers (FO)
- Air support assets
  - Suppression
  - Refueling
- Airborne Warning And Control System
- Joint Surveillance Target Attack Radar System
- Allied forces
- Threats
  - Airborne interceptors
  - Surface-to-air missiles
  - Anti-aircraft artillery
  - Small arms

- Targets
  - Troop units
  - Vehicles

In order to structure a test, the player cast has to be embedded in a dynamic operational scenario. The scenario supports detailed mission layout activities and time-sequenced events for the SUT. Some of the players on the list have very tightly coupled interactions with the SUT. Examples include friendly ground forces, enemy ground forces (targets), terminal threats, and the airborne FAC. Other agencies such as AWACS, Joint STARS, or the WOC have more loosely coupled interactions but may be important to SUT performance.

Step 3 is finished when the cast of players has been whittled down to those who play a role in the performance of the SUT in the selected task, and the measures of performance (MOPs) and measures of effectiveness (MOEs) have been developed for the SUT evaluation. The scenario developed in Step 3 is an operational scenario; a real world scenario -- not a test scenario. That comes later.

2.4 Step 4. Consider Using ADS

The activity described to this point is simply a test planning or test concept development approach. Step 4 is a switch point -- to include or not to include a detailed consideration of ADS use as part of the concept development methodology. In a few cases, the operating and test environments may be relatively simple. An example might be the testing of a new side arm. A test of such a system can be done live, in open air, and affordably. The example I have chosen is complex and highly interactive with a wide cast of players. In the complex case, it is reasonably clear that live, open air testing with the full cast of players is not affordable. Because of the large number of man-in-the-loop (MITL) interactions, it is also reasonably clear that representation of the environment in a stand-alone simulation will suffer credibility problems because we don't model human decision making very well. If the test planners are reasonably certain that the test environment cannot be adequately represented using the traditional test approaches, then they have two choices: accept the test limitations or explore ADS to see if the technology can make a better test within the fiscal constraints.

Stated succinctly, the decision associated with Step 4 is about the adequacy of the test scenario as compared with the operational scenario. In a world with no fiscal or safety constraints, the operational scenario and the test scenario would be identical. In the real world, the issue becomes "can we approximate reality with sufficient accuracy to have a satisfactory test." If the test planners cannot provide an appropriate test environment using traditional test approaches, then the answer is "no," and the planners should explore whether ADS can do anything to improve the situation. If the answer is "no," then the process moves along to Step 5. If the answer is "yes, we can provide a suitable test environment," then the planners can proceed with a traditional test plan for <u>that particular</u> operational task. Other tasks may require different approaches.

2.5 Step 5. Select a Player

Traditional testing shortfalls often include an insufficient number of test articles, insufficient number of threats, and inadequate representation of friendly force interactions. The process of ADS exploration begins with a visit to the player list developed in Step 3, and the first player on that list is the SUT. Depending on where the program is, the SUT may be available in a variety of forms. Early in the program, the SUT may only be available as a digital system model (DSM). Later the SUT may exist in brassboard form with a variety of subcomponents scattered among a variety of vendors. Eventually the SUT will be available in prototype or production version form, and a flight simulator version will emerge. (The DSM version is still available at this stage.)

2.6 Step 6. Determine Player Representation

The determination of a player representation will be made based on both the availability of representations and the test objectives. This step addresses both of these criteria. The planning team will need to investigate the available representations for each player beginning with the SUT. The planning team will also have to define the requirements for the test to meet the test objectives.

Let's assume that we have a prototype version of the SUT and a flight simulator exists. We also have a DSM form of the SUT. If the operational doctrine calls for a two-ship flight, then we have a requirement to represent two SUTs. One approach could be to couple the SUT manned flight simulator with another manned simulator that could represent the SUT and the communications types and channels for interflight communications. A facility like the Theater Air Command and Control Simulation Facility (TACCSF) at Kirtland Air Force Base, New Mexico, could represent a second version of the SUT at a reasonable cost. Most manned dome simulators could provide the visual representation of the TACCSF-generated wingman. The technology exists to input or overlay jamming energy on the communications link.

After looking at the SUT configuration choices, the planners can move on to the other players. If the player list is prioritized on the basis of the more direct interactions, then the more important players are addressed first. For each player, the test planners must have access to information about the various manifestations of the player. They must know what forms are available, and they must learn what they can about capabilities and costs for each form.

A facility like TACCSF could represent the airborne FAC complete with man-in-the-loop. If there was a higher fidelity requirement, a manned simulator of the FAC aircraft could be used. The communications links could be subjected to jamming in the same manner as the interflight links.

The targets and the friendly ground forces in the vicinity of the strike also have tight interactions with the SUT. Individual targets can be simulated in large numbers by a number of constructive simulations -- Janus serves as an example. Target visual representations can be piped to the simulator dome for the SUT. Friendly command and control centers of all types can be

represented at a level of fidelity tailored to test needs and cost. A corps tactical operations center (TOC), for instance, could be represented by a full-up, fielded TOC if testing was done in conjunction with some exercise. The TOC could also be represented, at decreasing levels of fidelity and cost, as a partially manned TOC in garrison; as an emulation of a TOC in TACCSF or a similar simulation facility; or by a single individual reading from a script. The same approach can be applied to other command and control elements such as the tactical air control party.

Another tight interaction involves the SUT and the threat systems in the strike area. The threats can be represented at any level from constructive to live. If high fidelity is a requirement (and in our hypothetical example it is) and since survivability is a measure of interest, then hardware-in-the-loop may be a minimum requirement.

As the players (the air operations center (AOC) and the WOC, for instance) become more and more peripheral, fidelity requirements decrease and scripted inputs or constructive models will suffice.

Step 6 involves a lot of research and learning.

2.7 Step 7. Fidelity Versus Cost

Step 7 involves the art of compromise between fidelity and cost. With the information gleaned in Step 6, the test planners are in a position to make reasoned choices about the players in the test and the appropriate form of representation for each of them. Rough order of magnitude (ROM) costs are adequate in the test concept development process. Costs are refined in detailed test planning.

2.8 Step 8. Evaluate Adequacy of the Environment

When the process reaches Step 8, the question facing the planners involves the adequacy of the environment which will be created by the interactions of the players selected. Each time Steps 5 through 7 are executed, the planners must ask whether more players are needed. If so, they return to Step 5. Step 5 is executed repeatedly until the test planners are satisfied that the test environment is rich enough in terms of meaningful interactions to support a sound test.

2.9 Step 9. Initial Planning

When the test planners are satisfied with the test concept for a given operational task, they can proceed with initial test planning for the associated test. The initial planning is conducted to the level required by Step 11.

2.10 Step 10. Additional Tasks

Step 10 involves the examination of the functionalities of the SUT, and the assessment of the necessity for further testing for additional operational tasks. If there are additional operational tasks that differ enough from those already addressed in test planning to this point, then the planners need to loop back to Step 2 of this process and develop another test concept. Planning cannot move on to Step 11 until initial planning has been completed for all operational tasks.

2.11 Step 11. Develop Master Plan

The task associated with Step 11 involves the deconfliction and coordination of each of the individual task-oriented test segments. Essentially Step 11 involves the development of the master plan and schedule.

In summary, this is a top-level test concept development process which incorporates decision elements associated with the use of ADS for test and evaluation. It is only intended as an example, and each test program is going to have unique aspects which will require planners to use creativity and imagination. Hopefully this outline approach provides the test planners with an understanding that ADS offers test opportunities that were never there before. ADS can be used to good effect at reasonable cost if it is used intelligently. There are many things ADS won't remedy, but there are many things it will. ADS is a technology set which should be considered during test planning. If it doesn't make sense to use it, don't use it. On the other hand, don't dismiss it just because you think it's too hard, or too exotic, or too expensive. Detailed test planning approaches are discussed in the test planning methodology section which follows.

3.0 ADS-Based Test Planning and Implementation Methodology

Assuming the decision is made to implement ADS-based testing, the following methodology applies. This methodology follows the steps given in the HLA FEDEP model [Ref. 1]. In comparing these guidelines with the FEDEP model, note that the terms "ADS architecture" and "distributed test" used here equate to the term "federation" in the FEDEP model, and the terms "facilities," "participants," and "players" used here equate to the term "federates" in the FEDEP model.

The FEDEP model groups the activities needed to develop and execute a distributed test into six steps.

Step 1: The test sponsor or evaluator and the distributed test development team define and agree on a set of objectives and document what must be accomplished to achieve those objectives. This is a test planning step and is addressed by the test planning methodology.

Step 2: A representation of the real-world domain of interest is developed and described in terms of a set of required objects and interactions. Most of the activities under this step are addressed by the test planning methodology.

Step 3: Distributed test participants (federates) are determined, and required functionalities are allocated to the participants.

Step 4: The federation object model (FOM) is developed (if HLA is implemented), participant agreements on consistent databases/algorithms are established, and modifications to federates are implemented (as required).

Step 5: All necessary distributed test implementation activities are performed, and testing is conducted to ensure interoperability requirements are being met.

Step 6: The distributed test is executed, outputs are generated, and results provided.

The FEDEP model breaks the six steps into activities, as shown in Table 1. The following subsections describe the activities for each step in more detail. Where appropriate, lessons learned from Joint Advanced Distributed Simulation (JADS) testing experience are given. Also, the cost impact factors applying to selected steps are discussed in Appendix A, Cost Factors For ADS-Based Testing, which lists the 15 top cost factors in order of decreasing impact. In addition, Appendix B, Guide to the VV&A of an ADS-Enhanced Test Environment, discusses verification, validation, and accreditation (VV&A) considerations which apply to each FEDEP step.

Table 1. Distributed Test Planning and Implementation Activities

STEP	ACTIVITIES
1. Define Distributed Test Objectives	1.1 Identify Needs 1.2 Develop Objectives
2. Develop Conceptual Model	2.1 Develop Scenario 2.2 Perform Conceptual Analysis 2.3 Develop Test Requirements
3. Design Distributed Test	3.1 Select Participants 3.2 Allocate Functionality 3.3 Prepare Plan
4. Develop Distributed Test	4.1 Develop FOM 4.2 Establish Participant Agreements 4.3 Implement Participant Modifications
5. Integrate and Test Architecture	5.1 Plan Execution 5.2 Integrate and Test ADS Architecture
6. Execute Distributed Test and Analyze Results	6.1 Execute Distributed Test 6.2 Process Output 6.3 Prepare Results

Although the FEDEP steps are presented in a sequential fashion, experience has shown that many of the activities in Table 1 are actually cyclic with extensive feedback among activities and/or concurrent. Implementers should not enforce a strict waterfall approach to the steps given. Not only may variations in the order of the activities be appropriate, but it is frequently necessary to revisit previous activities as the distributed test requirements and design become more mature.

3.1 Step 1. Define Distributed Test Objectives

According to the FEDEP model, the purpose of the activities for this step is to define and document a set of needs that are to be addressed through the development and execution of a distributed test and to transform these needs into a more detailed list of specific test objectives. The key activities for this step and the activity inputs and outputs are shown in Figure 2 [Ref. 1].

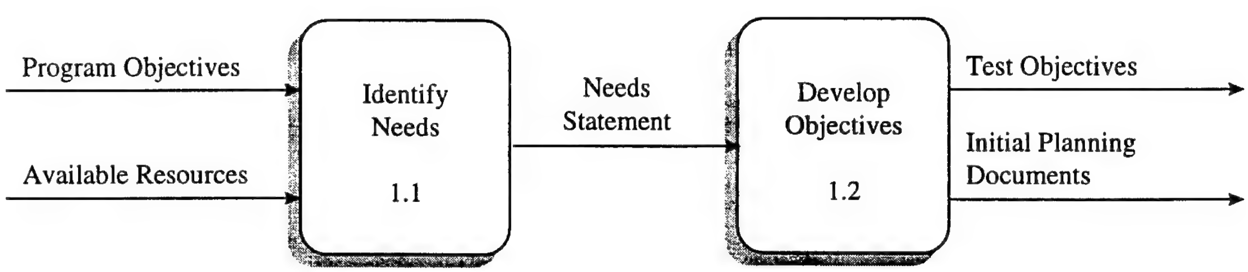


Figure 2. Define Distributed Test Objectives

JADS experience has shown the importance of forming an integrated product team (IPT) early in the planning stage of a distributed test. A distributed test usually brings together organizations unfamiliar with conducting coordinated, distributed T&E tests. The linking procedures, communications, test control, and security aspects are different from stand-alone facility tests. IPT meetings help ensure a common understanding of these unique aspects. Minutes from the meetings should be kept and action items tracked throughout the test development effort in order to provide a more structured and cohesive approach and to assist in resolving issues. An efficient method for conducting IPT meetings is by use of secure video teleconferences (VTCs). VTCs reduce the need for key personnel to travel to a common location and result in less time away from the job of preparing for the distributed test.

A key member of the IPT is the system integrator. The system integrator is needed to oversee the distributed test development by coordinating the integration of the various organizations/facilities involved. The system integrator must be able to grasp the technical and administrative issues involved and must have the authority to proactively resolve any problems (cost impact factor of rank #7 - see Appendix A).

3.1.1 Activity 1.1 - Identify Needs

According to the FEDEP model, the primary purpose of this activity is to develop a clear understanding of the problem to be addressed by the distributed test. Inputs to this activity are the program objectives and information on resources available to support a distributed test. The main output of this activity is a needs statement which includes the following

- High-level descriptions of critical systems of interest
- Coarse indications of fidelity and required behaviors for simulated players
- Key events that must be represented in the distributed test scenario
- Output data requirements
- Resources that will be available to support the distributed test (e.g., funding, personnel, tools, facilities)
- Any known constraints which may affect how the distributed test is developed (e.g., due dates, security requirements)

Note that most of these items should have been determined during application of the test concept development methodology. However, their determination should be repeated here to check/validate the earlier findings.

3.1.2 Activity 1.2 - Develop Objectives

According to the FEDEP model, the purpose of this activity is to refine the needs statement into a more detailed set of specific objectives for the distributed test. This activity requires close collaboration between the distributed test user/sponsor and the test development team to ensure that the resulting objectives meet the stated needs. The user/sponsor must clearly define, communicate, and document test requirements early in the test planning phase. The main input

to this activity is the needs statement from the previous activity. The main outputs of this activity are a statement of the test objectives and initial planning documents. The test objectives statement should include the following information

- A prioritized list of measurable test objectives
- A high-level description of key ADS architecture characteristics (e.g., repeatability, portability, time management approach)
- Needed equipment, facilities, and data
- Operational context constraints or preferences, including friendly/threat/civilian order of battle, geographic regions, environmental conditions, and tactics
- Identification of security position, including estimated security level and possible designated approval authority(s)
- A configuration management approach
- Identification of tools to support scenario development, conceptual analysis, VV&A (see Appendix B for VV&A activities to consider) and test activities, and configuration management

The initial test planning documents should include a test development plan with an approximate schedule and major milestones and initial versions of the test plan, accreditation plan, and security plan (cost impact factor of rank #12 - see Appendix A).

Note that most of these items should have been determined during application of the test concept development methodology. However, their determination should be repeated here to check/validate the earlier findings.

3.2 Step 2. Develop Conceptual Model

According to the FEDEP model, the purpose of this step is to develop an appropriate representation of the real-world domain that applies to the distributed test environment and to develop the test scenario. During this step, test objectives are transformed into a set of specific requirements for use as success criteria during ADS architecture testing. The key activities for this step and the activity inputs and outputs are shown in Figure 3 [Ref. 1].

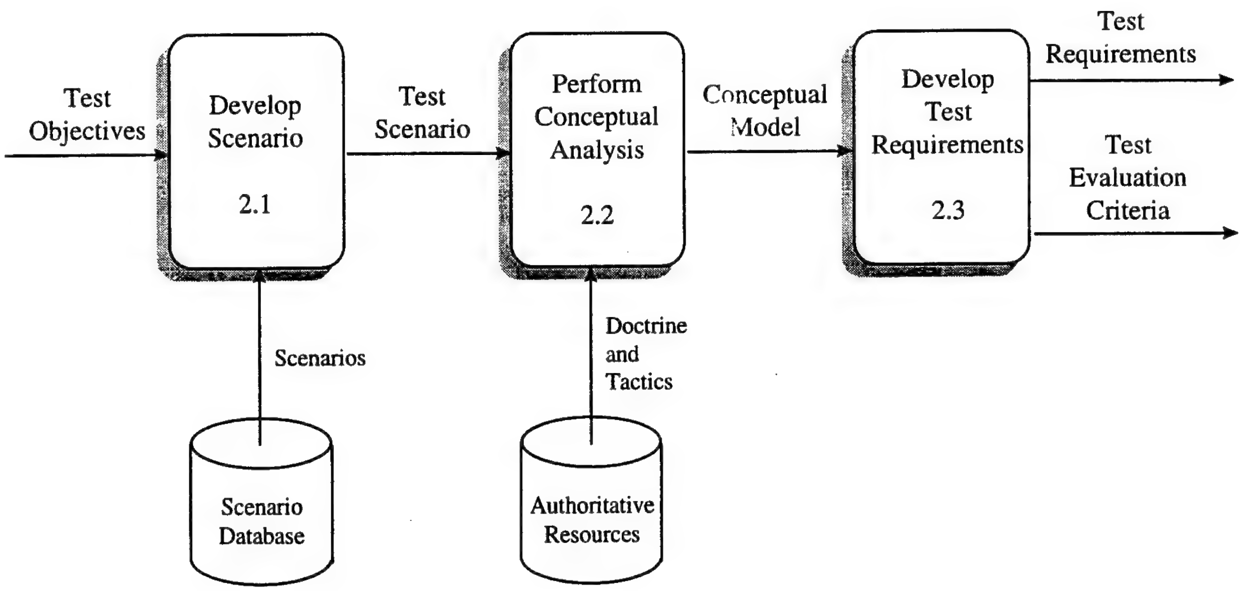


Figure 3. Develop Conceptual Model

3.2.1 Activity 2.1 - Develop Scenario

According to the FEDEP model, the purpose of this activity is to develop a functional specification of the test scenario. The primary input to this activity is the operational context constraints specified in the test objectives statement, although existing scenario databases may also provide a reusable starting point for scenario development. The primary output is the test scenario. The scenario description should include the following

- The types and numbers of major players that must be represented in the distributed test
- A functional description of the capabilities, behavior, and relationships among these major players over time
- A specification of relevant environmental conditions that impact or are impacted by players in the distributed test
- Initial/terminal conditions and the specific map projection chosen for the scenario

Note that most of these items should have been determined/developed during application of the test concept development methodology. However, their determination/development should be repeated here to check/validate the earlier findings.

3.2.2 Activity 2.2 - Perform Conceptual Analysis

According to the FEDEP model, the purpose of this activity is to produce a conceptual model of the ADS environment. The primary inputs to this activity are the test scenario from the previous activity, the test objectives statement, and any doctrine and tactics appropriate for the scenario. The output of this activity is the conceptual model which provides an implementation-independent representation that serves as a vehicle for transforming objectives into functional

and behavioral capabilities, and provides a crucial traceability link between the test objectives and the design implementation. The conceptual model is a description of the players, their actions, and any interactions among players that need to be included in the distributed test in order to achieve all test objectives. These are described without any reference to specific simulations that will be used.

Once this is completed, the conceptual model needs to be carefully evaluated before the next activity. Revisions to the original federation objectives may be defined and implemented as a result of this feedback.

Note that the conceptual model description should have been developed during application of the test concept development methodology. However, this development should be repeated here to check/validate the earlier findings.

3.2.3 Activity 2.3 - Develop Test Requirements

According to the FEDEP model, the conceptual model will lead to the definition of detailed distributed test requirements and test evaluation criteria. These requirements should be based on the distributed test objectives, should be directly testable, and should provide the implementation-level guidance needed to design and develop the distributed test (cost impact factor of rank #9 - see Appendix A). The test requirements will also be the basis for the criteria for evaluating test results (see Fig. 3). Major top-level requirements which should be addressed include the following (although some of these requirements should have been developed during application of the test planning methodology, their development should be repeated here to check/validate the earlier findings).

- Fidelity requirements.
  - The fidelity requirements for all players represented in the distributed test scenarios must be determined. The required fidelity depends upon the maturity of the SUT, the SUT test objectives, and the nature of the interactions between the SUT and the other players.
  - The fidelity of the SUT representation may be limited to available models or test articles. For example, during early DT&E, a low-fidelity digital model may be the only SUT representation available, but during late DT&E and OT&E, possible SUT representations may include high-fidelity digital models, hardware-in-the-loop (HWIL) labs, and live test articles. If multiple SUT representations are available with varying levels of fidelity, the choice will usually be driven by the SUT test objectives and other considerations such as availability and cost.
  - The required fidelity for the other players normally depends on the fidelity of the SUT, the sensitivity of test objectives/measures to player interactions with the SUT, the strength of the interactions with the SUT (players that have strong, or tightly coupled, interactions with the SUT will generally have higher fidelity requirements than those which do not), the test objectives, and cost and availability considerations.
  - It is important to involve SUT experts from the beginning of the distributed test program in order to determine fidelity requirements, establish the data and instrumentation requirements, verify/validate the analytical approach, assist in the development of test

matrices and test procedures, and provide overall SUT expertise. The support of more than one SUT expert should be planned for (and budgeted for) throughout the test.

- Interaction requirements.
  - Use the conceptual model to determine the data types that must be exchanged among players to permit interactions, including entity state data, tactical messages, launch and detonation indications (if appropriate), and trial start and stop notification.
- Latency requirements (cost impact factor of rank #4 - see Appendix A).
  - Determine the maximum acceptable latency and latency variations for each pair of interacting players. The maximum latency requirement will be determined by how closely coupled the interactions are and by the maximum allowable error in the location of one player as perceived by the other.
    - For example, if the two players are reacting to each other in real time (i.e., a tightly-coupled, closed-loop interaction), the maximum allowable latency will be relatively smaller in order to achieve an acceptable error in the perceived locations of the players. (An estimate of the position error for one player as perceived by the other is given by the latency of the entity state data multiplied by the first player's velocity; hence, an estimate of the maximum allowable latency would be given by the maximum acceptable position error divided by the first player's velocity.)
    - An air-to-air missile guiding to intercept an aircraft target which is, in turn, maneuvering in order to evade the missile is a specific example of a tightly coupled, closed-loop interaction. In this case, the maximum acceptable position error might be the lethal radius of the missile, so that the target and missile do not disagree on whether the target was killed.
    - For human-in-the-loop interactions (e.g., two pilots reacting to each other), the rule of thumb for the maximum acceptable latency is about 100 milliseconds.
    - For uncoupled, or open-loop, interactions, there may be no maximum acceptable latency requirement. An air-to-air missile guiding to intercept an aircraft target which is executing a scripted, nonreactive maneuver is a specific example of an uncoupled, open-loop interaction. (This is the typical scenario for a live fire test against an unmanned drone target.) Another specific example would be a surface-to-surface missile guiding to a stationary ground target. In both cases, latency would not affect the outcome of the missile attack as perceived by either player.
    - Random sample-to-sample latency variations in the entity state data received over a wide area network (WAN) have been observed during JADS testing and result in an uncertainty in the transmitting player's position as perceived by the receiving player [Ref. 2]. An estimate of the position uncertainty is given by the standard deviation of the latency values multiplied by the transmitting player's velocity. Hence, an estimate of the maximum allowable latency variations would be given by the maximum acceptable position uncertainty divided by the transmitting player's velocity.
- Data reliability requirements.
  - Determine the maximum acceptable level of ADS-induced errors, such as dropout rate and out-of-order data messages. The allowable errors may vary with data types. For example, some loss of entity state data may be tolerable for short durations if dead reckoning can supply the missing data within acceptable error tolerances. However, the loss of a single discrete message may invalidate an entire trial. This determination may

drive the reliability requirement for data transport and guide the selection of data transport protocols.

- Data analysis requirements.
  - Draft a preliminary data management and analysis plan (DMAP) that details the analysis approach for each test objective. From the DMAP determine which data must be collected and the analysis techniques to be applied.
  - Identify all data required to achieve test objectives. This generally includes all data exchanged among players, data needed for test control and monitoring, and data which are not exchanged but are needed for analysis. An example of the latter is internal simulation data which are not transmitted to other players, but which must be analyzed/monitored to verify proper operation of the simulation during linked operations.
  - Identify all data required to analyze network performance and the impact of network performance on the players (e.g., impact on SUT data validity).
  - For standard analysis techniques (e.g., statistical or regression analysis), identify commercial or government off-the-shelf tools that can be used for data analysis/reduction.
  - Determine the requirements for any custom analysis/processing tools.

After all these requirements have been developed, the capability of the support agencies (e.g., simulation or range facilities, networking and engineering team) to support the test must be clearly stated and documented, such as by a statement of capability (SOC). The SOC documents the set of requirements and provides a clear statement of the support agency's capabilities, constraints, and limitations in meeting those requirements.

The support agencies also need to create an integrated, detailed work breakdown structure (WBS) early in the program which is consistent with the SOC. It is also important to have accurate cost estimates allocated against the WBS tasks in order to help program management decisions.

3.3 Step 3. Design Distributed Test

According to the FEDEP model, the purpose of this step is to identify, evaluate, and select all distributed test participants (federates), allocate required functionality to those participants, and develop a detailed plan for test bed development and implementation. The key activities for this step and the activity inputs and outputs are shown in Figure 4 [Ref. 1].

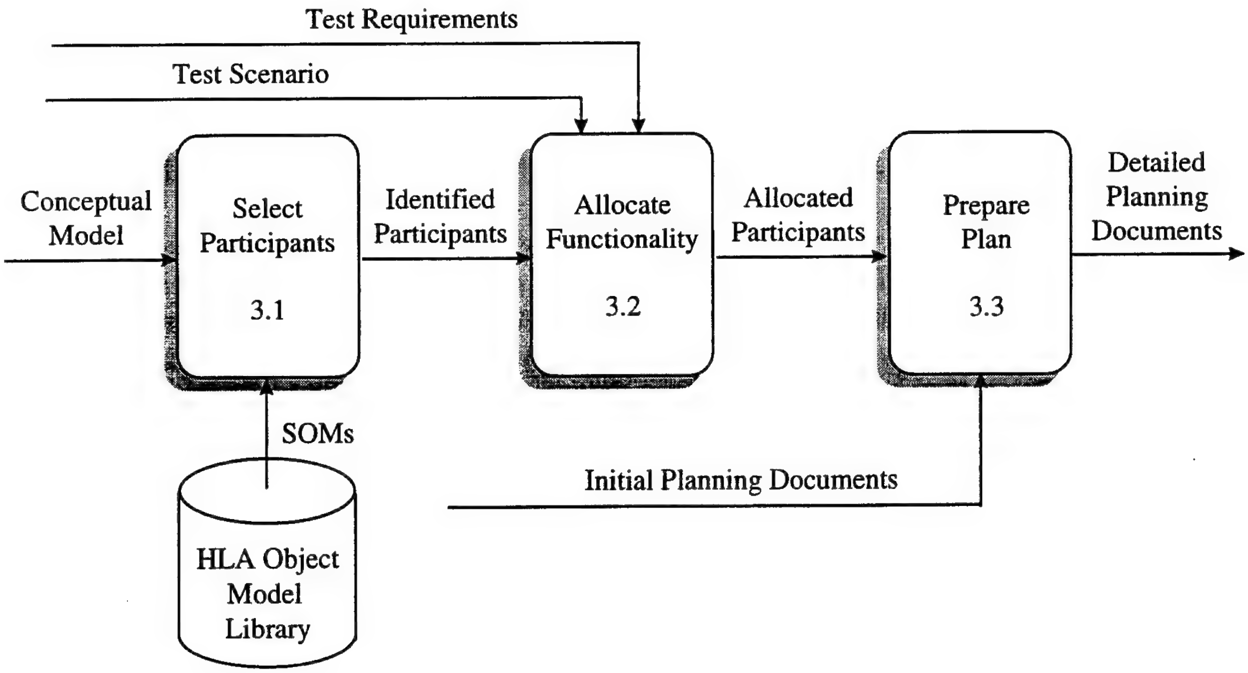


Figure 4. Design Distributed Test

3.3.1 Activity 3.1 - Select Participants

According to the FEDEP model, the purpose of this activity is to determine the suitability of individual player representations (e.g., simulations, HWIL labs, or live players/ranges) to become participants in the distributed test. The input to this activity is the conceptual model developed in Activity 2.2. The output is an identification of the specific player representations selected.

This activity involves the identification of specific simulations, HWIL labs, or live players/ranges to be used in the distributed test and their locations. This selection is driven primarily by the following factors:

- Perceived ability of potential representations to represent the players' behavior and the interactions specified in the conceptual model
- Fidelity requirements for each player
- Managerial constraints, such as availability (cost impact factor of rank #10 - see Appendix A), cost, schedule, and security considerations
- Technical constraints, such as VV&A status and portability
- For live players, the selection of particular test ranges is also driven by considerations of range instrumentation quality and quantity and data processing capability

A good source of information on available simulations is the HLA Object Model Library (OML) which contains the simulation object models (SOMs) describing many simulations. The searching and browsing features provided by the OML expedite the search of the electronic libraries of SOMs. However, it is highly advisable to directly verify the advertised capabilities of the facilities/instrumentation before making a selection.

If no available representations meet the requirements for one of the players, either the requirements must be revised or a new representation must be developed.

3.3.2 Activity 3.2 - Allocate Functionality

According to the FEDEP model, the purpose of this activity is to allocate the responsibility to represent the entities and actions in the conceptual model to the participants. This activity will allow for the assessment of whether the set of selected participants provides the full set of required functionality or whether one or more of the representations will need to be enhanced to meet the distributed test requirements. The inputs to this activity are the identified participants from the previous activity, along with the test requirements, the test scenario, and the conceptual model. The output is allocated requirements for the participants, including any requirements for modifying existing player representations or designing new ones.

Requirements need to be allocated to the participants before the architecture can be designed and before the requirements for modifying existing player representations or designing new ones can be determined. These allocated requirements include the following.

- Data requirements.
  - Determine the rates of data exchanged among the players. For each pair of players, compare the rate that the transmitting player generates data with the rate that the receiving player requires inputs (e.g., a receiving simulation's frame rate).
    - If the receiving player requires data at a lower rate than generated by the transmitting player, determine if the transmitting player's output can be filtered down to the receiving player's required input rate before the transmitting player's data are interfaced to the WAN link connecting the two.
    - If the receiving player requires entity state data at a higher rate than generated by the transmitting player, determine if the received data can be dead reckoned at the receiving player's node in order to produce the required input rate. This is done by comparing dead reckoning errors (e.g., difference between the transmitting player's dead reckoned and interpolated positions) to the receiving player's entity state data accuracy requirements. If the dead reckoning errors are unacceptable, there are three potential solutions: (1) increase the order of the dead reckoning algorithm (e.g., use acceleration as well as velocity), (2) increase the generation rate of the transmitting player to the value required by the receiving player, if possible, or (3) interpolate the transmitting player's entity state data at the receiving node. (Note that the third solution requires additional latency, since two successive entity state data sets must be received before interpolation can be performed; hence, the receiving player is always at least one transmitting player update time behind; this solution is only feasible if the additional latency is within required limits – see latency requirement determination below.)
  - Determine the time-space-position information (TSPI) accuracy and smoothness requirements for live players. This determination depends on the test objectives and the data input requirements of the player receiving the TSPI data. For example, if the TSPI

data will be used as the basis for evaluating the accuracy of shooter targeting messages, the TSPI accuracy should be at least an order of magnitude more accurate than the targeting messages. An example of a TSPI smoothness requirement is target entity state data being input into a missile HWIL laboratory. If the TSPI data input is not sufficiently smooth, the motion of the missile flight table can exceed allowable limits and prevent the missile from following the target motion and even, in extreme cases, cause the missile simulation to crash.

- Determine the requirement for data time-stamp accuracy. If latency is to be measured, the time stamps must be accurate to the required latency determination accuracy. For most applications, an accuracy of 0.1 milliseconds is more than adequate.
  - Also, the time sources that determine the time stamps at distributed locations must be synchronized to within the required time-stamp accuracy. Techniques for achieving this synchronization requirement are discussed in References 3 through 5. Implementation of these techniques may also impact hardware requirements (e.g., Inter-Range Instrumentation Group (IRIG), global positioning system (GPS)) and software requirements (e.g., network time protocol (NTP)).
  - During two of the JADS tests, a time server slaved to GPS time was used to synchronize all loggers. The JADS implementation used XNTP, a free software tool from the University of Delaware (can be downloaded from http://www.eecis.udel.edu/~ntp/). XNTP uses a UNIX™ daemon, xntpd, to synchronize a local workstation clock to a central time source. XNTP takes the local clock performance into account as it operates. The software also considers the network latencies and performance, thereby allowing the use of XNTP across LANs and WANs. During JADS testing, this technique allowed the time sources in the data loggers, which were separated by up to a couple of thousand miles, to be synchronized to within 0.1 milliseconds of GPS time. More information on XNTP can be found in Reference 5.
- Determine the classification of the data and any security handling requirements (cost impact factor of rank #6 - see Appendix A). This is generally driven by the SUT security classification guide.
  - Operations security (OPSEC) requirements for a distributed test must be determined and coordinated early in the program especially given the various organizations involved and their different procedures. Issues to be addressed include the need for an OPSEC plan; if an OPSEC plan is required, an agreement either to use an already approved OPSEC plan or to draft a new plan; the consistency of OPSEC requirements among the various organizations and programs; OPSEC requirements in test control/conduct, including the use of "For Official Use Only" test cards and/or the use of secure communications.
- Document all data exchanges with an interface control document (ICD).

- Data synchronization requirements.
  - Determine the requirement for synchronizing multiple data inputs at a receiving node. For example, shooter and target entity state data may be generated by different simulations at different nodes and have to be synchronized before input to a missile simulation. As another example, entity state data may have to be synchronized to messages at a receiving node.

- Real-time data processing requirements.
  - Examples of data processing requirements.
    - Real-time data processing needed to achieve the required TSPI accuracy (as determined previously) for live players. For example, during the JADS live fly phase (LFP) test [Ref. 6], Eglin Air Force Base, Florida, developed a TSPI data processor (TDP) that merged several types of TSPI data in near real time (processing latencies of about 2 seconds). The TDP combined real-time aircraft inertial navigation system, GPS, and ground tracking radar data to calculate more accurate kinematics estimates of the aircraft.
    - Real-time telemetry processing limitations. Certain live player maneuvers may screen the telemetry transmission path. Line-of-sight telemetry reception requirements may limit player locations/altitudes, attitude changes, and configuration (e.g., a live aircraft may not be able to carry external fuel tanks that could block the telemetry antenna).
    - Real-time data processing needed to achieve the required synchronization of multiple data inputs at a receiving node. If there are no latency requirements (such as for the case of uncoupled, open-loop interactions), buffering and time alignment of the data can be used. If there are requirements to maintain low processing latencies, entity state data can be dead reckoned to a common data input rate.
    - Real-time data processing needed to achieve latency compensation. For low latency interactions, entity state data to be input into a receiving simulation can be dead reckoned to the current local time in order to compensate for latency effects. Note that the clocks at the different nodes need to be synchronized in order for this latency compensation technique to be effective.
- Data collection/instrumentation requirements.
  - Determine data collection/instrumentation requirements based on data requirements.
    - Select instrumentation types and data logging software. Existing loggers should be evaluated carefully to ensure their adequacy. JADS found that the available loggers did not have the required time-stamp accuracy, and it was necessary for JADS to develop their own loggers. JADS developed two types of loggers for its tests.
      - Passive, or stealth, loggers were developed for use at each site during tests in which all data were broadcast among sites (e.g., for those tests using distributed interactive simulation (DIS) protocol data units (PDUs)).
      - In-line loggers were developed for use within each federate for HLA-based testing.
    - Determine instrumentation locations.
  - Determine the data that must be recorded in order to support post-test analysis.
    - In some cases, the same data may have to be recorded at multiple locations in order to verify data integrity during transport. Identify the data source and each required recording location.
    - Some data may not be transported among nodes but may still be needed for analysis (e.g., internal simulation data). These data are best recorded within the generating player/simulation.

These allocated requirements are used to assess the capabilities of the player representations selected or to determine design requirements for any missing representations. This assessment

may reveal the need to modify the selected representations (cost impact factor of rank #2 - see Appendix A). Requirements for potential modifications are determined as follows.

- Determine if any simulation modifications will be necessary to utilize external inputs. These may include the following.
  - Modifications necessary to distribute incoming data to all required hardware systems and software programs.
  - Modifications necessary to input data into simulation code in real time.
  - Modifications necessary to meet synchronization requirements.
- Determine if any simulation modifications will be necessary to generate required outputs.
  - Determine the method to be used for achieving the output data time-stamp accuracy requirement. Also, it may be necessary to time stamp internally logged simulation data with absolute GPS-based time stamps rather than the more typical relative time stamps in order to correlate data (GPS time stamps can provide a unique means for tagging data messages) and perform latency analyses.
- Determine if any range data processing modifications will be necessary to meet TSPI accuracy, smoothness, and latency requirements.
- Determine if any facility modifications will be required for a replay capability that can be used during integration testing.

If missing player representations must be developed, the additional requirements are used for the design requirements. The decision to design and develop a new representation can have severe cost and schedule impacts on the distributed test, since this can be the single largest cost of an ADS-based test (cost impact factor of rank #1 - see Appendix A). For example, the JADS End-to-End (ETE) Test needed a ground emulation of the Joint STARS aircraft radar subsystem and operator work stations, and no adequate simulation existed. Thus, the decision was made to develop the required simulation, and its cost was about 40% of the total ETE Test budget.

3.3.3 Activity 3.3 - Prepare Plan

According to the FEDEP model, the purpose of this activity is to develop a coordinated plan to guide the development, test, and execution of the distributed test. The inputs to this activity are the initial planning documents prepared during the development of the test objectives (Activity 1.2) and the allocated participant requirements. The output is the detailed planning documents.

The following documents are needed.

- A detailed test plan that contains the following.
  - Documentation of all test objectives and requirements.
  - Descriptions of test events designed to accomplish the test objectives.
    - Descriptions of the scenarios to be used during the test events.
    - The number of trials to be performed during each test event. The number selected should be consistent with those needed to achieve desired confidence intervals.
  - Descriptions of the test configuration and instrumentation.

    - A plan for configuration management should also be included. Configuration management is a critical concern during the design and execution of a distributed test and a formalized, disciplined approach is needed (cost impact factor of rank #16 - see Appendix A). The use of an IPT can be an effective way to maintain configuration control during the planning phase of a test. This should include a methodical approach to network management and troubleshooting. Since problems are part of the process, the network configuration cannot be "frozen" until there is an agreed upon "baseline." However, the configuration control process/procedures must be established at the beginning of the program and followed until the end.
  - Identification of any software tools to be used for configuration management, VV&A (see Appendix B for VV&A activities to consider), or testing.
  - Identification of resources needed to complete the test including funding, personnel, equipment and materiel, and facilities.
  - Descriptions of all activities required to accomplish the test including schedules with key milestones. Some considerations in setting up schedules include the following (cost impact factor of rank #11 - see Appendix A):
    - Adequate time must be allotted for data analysis between test events during both integration testing and test execution. There is a tendency to underestimate the time required to adequately analyze the large volume of data collected in distributed test events. As a result, some problems from one mission may not be fully diagnosed and fixed before the next mission. Rehearsal of the analysis procedures should be used to better estimate the time required for adequate analysis between test events.
    - When scheduling live assets, allowances must be made for periodic military system inspections (e.g., aircraft phase inspections), equipment breakdown, and higher priority missions. It is wise to plan both a primary and a contingency date for each mission.
    - Another consideration for live assets is the use of piggyback missions. Piggyback missions can be used to support integration testing and check-out. However, such missions cannot be counted on, and backup dedicated missions should also be scheduled.
    - The schedule should track the WBS. Scheduling software tools, such as Microsoft® Project, are useful for deconflicting resources and for managing the tasks.
  - Descriptions of the roles and responsibilities of all organizations participating in the test.
- A detailed DMAP which specifies the data requirements, data sources, analysis procedures, and the analysis products required to accomplish each test objective.
  - Data reduction and analysis procedures may be aided by the JADS Analysis Toolbox.[1]
- A detailed VV&A plan (see Appendix B) which includes integration testing to verify architecture performance (cost impact factor of rank #8 - see Appendix A).

[1] For further information on the JADS Analysis Toolbox, please contact the JADS program office or visit the JADS website at http://www.jads.abq.com where it will be available until March 2001. After that date, information on the toolbox will be available at Headquarters Air Force Operational Test and Evaluation Center (HQ AFOTEC) History Office (HO), 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 and at the Science Applications International Corporation (SAIC) Technical Library, 2001 North Beauregard St. Suite 800, Alexandria, Virginia 22311.

- A detailed ICD which specifies all data to be passed between simulations/range facilities. This data specification includes data content, timing, formats, and coordinate systems (including all coordinate transformation equations). The ICD will also specify data bases which must be available at all facilities (see Activity 4.2). The ICD is essential for ensuring successful integration of the simulations/range facilities and must be rigorously enforced.
- If HLA is to be implemented, the documentation contained in the Federation Execution Planners Workbook (FEPW) should be completed. See Reference 1 for details.

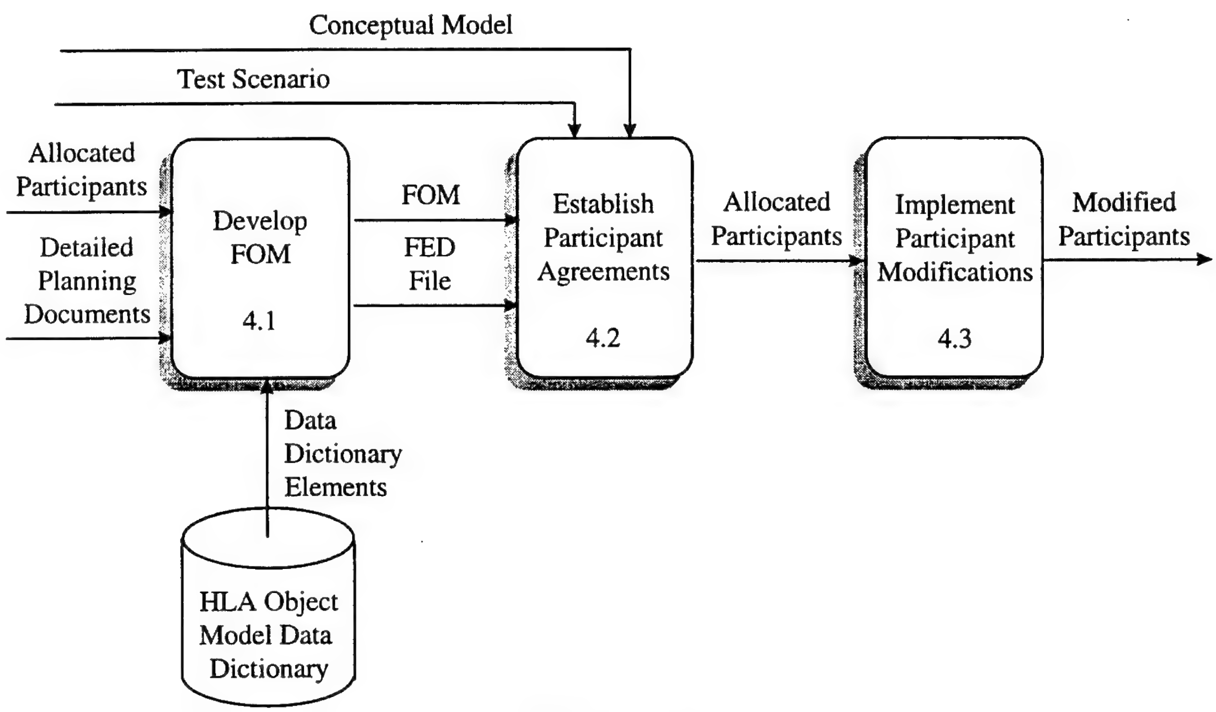
Detailed network design should begin as soon as possible during test planning, but no later than this activity. Early definition of network requirements allows for timely selection of hardware and software alternatives and allows enough time to acquire the right components through government channels and contracts. Also, the network requirements should be revisited frequently and the design updated accordingly throughout the test planning process. Key considerations in designing the network include the following.

- Determine if data from each node will be broadcast, multicast, or unicast (transmitted point-to-point). The most common implementation of DIS uses broadcasting of data. On the other hand, both DIS and HLA implementation allow multicast or unicast only to those nodes (federates) subscribing to the particular data. This determination impacts WAN bandwidth requirements, as broadcast requires the largest bandwidth and unicast the least.
- Determine if data are to be transmitted using best effort or reliable procedures based on data transport reliability requirements. For example, the user datagram protocol (UDP) is not a good choice if highly reliable data transmission is needed; the transmission control protocol (TCP) is better for reliable transport. Note that reliable transport mechanisms will result in higher latency than best effort transport.
- Determine the network security approach to be implemented (cost impact factor of rank #6 - see Appendix A).
  - Designate a security point of contact, perform a security risk assessment, and develop a security concept of operations.
  - Determine the data encryption requirements based on the classification of the data to be passed over the WAN.
  - Detailed procedures for secure/encrypted operations must be developed, and approval for their use must be obtained from all affected designated approval authorities. Preparations for secure network operations includes the following:
    - Coordinating the security memoranda of agreement (MOAs) between the organizations involved. Allow 3-4 months for the MOA process.
    - Obtaining accreditation for networks, facilities, rooms, etc.
    - Obtaining a communications security (COMSEC) account.
    - Ordering keying material for encryption equipment.
- Determine the WAN bandwidth requirement.
  - Determine the average and maximum aggregate data rate by adding rates from each player transmitted over the WAN. A rule of thumb for the bandwidth requirement is given by the aggregate data rate plus a 50% - 100% margin for overhead, bursty and unanticipated traffic.

- If the WAN is also to be used for voice communications, the anticipated data rate must be added to the aggregate for estimating the bandwidth requirement.
- Conduct surveys of each site to be linked by the network.
  - The surveys are used to determine each facility's communications architecture and requirements and to determine the physical space requirements for tester-supplied equipment and personnel. Two surveys are recommended: the first should occur early during Step 3 (design distributed test), and the second should be during this activity.
  - The site surveys should include the following.
    - Establish points of contact (POCs) at each site.
    - Determine the locations of key network components, such as the point of presence, network equipment, etc.
    - Determine the availability of space, power, and telephones.
    - Identify security issues, such as POCs, local restrictions, etc.

3.4 Step 4. Develop Distributed Test

According to the FEDEP model, the purpose of this step is to develop the FOM (if HLA is to be implemented), modify the simulations/range facilities if necessary, and prepare the distributed architecture for integration and test. The key activities for this step and the activity inputs and outputs are shown in Figure 5 [Ref. 1].



FED = federation

Figure 5. Develop Distributed Test

3.4.1 Activity 4.1 - Develop FOM

According to the FEDEP model, the purpose of this activity is to develop the FOM. The inputs to this activity are the detailed planning documents and the allocated participant requirements. The outputs are the FOM and federation execution data (FED) file, if appropriate.

If HLA is to be implemented, a FOM must be prepared. The FOM serves to document the data exchanges required among the federates to meet the federation objectives. Reference 1 outlines several approaches that can be used to develop the FOM (including use of the HLA Object Model Data Dictionary) and to generate the FED file, and the DMSO HLA website contains additional information and guidance.

For successful HLA implementation, it is important for key personnel to attend HLA training classes early in the program. This will help clarify what HLA consists of and will help unify the vision of what the HLA portion of the test should entail.

3.4.2 Activity 4.2 - Establish Participant Agreements

According to the FEDEP model, the purpose of this activity is to establish all agreements among participants necessary for a fully consistent, interoperable, distributed simulation environment. The inputs to this activity are the test scenario, the conceptual model, and the FOM (if HLA is to be implemented). The output is revised participant allocated requirements, including any requirements for additional modifications.

During this activity, the participant interaction requirements are finalized and documented in the ICD including the following.

- Determine the data protocols to be used.
  - Decide if standard protocols (e.g., DIS PDUs) are to be used or if it would be advantageous to keep data in formats/coordinate systems generated by the players. If the transmitting and receiving players use the same coordinate system (which is different from the geocentric DIS coordinate system), processing time would be increased by using DIS PDUs and coordinate transformation errors could result.
  - Identify any data exchanged among players that is best kept in its tactical protocol. For example, if the distributed test involves the T&E of an integrated launcher/missile system, keeping the prelaunch data exchanged between a shooter and missile in its tactical protocol is appropriate for accomplishing the SUT T&E objectives and eliminates the risk of data corruption from unnecessary protocol transformations.
- Interface requirements. Note that linking of facilities using ADS can require significant interface hardware and software development. ADS implementation is not "plug and play."
  - Simulation interfaces.
    - Network interface units (NIUs) of some sort are necessary if two simulations cannot communicate directly in a common language and on a common timeline. The NIUs

interface the simulation output/input to the WAN. NIUs need to be carefully designed, since they can be a major source of both error and processing delays.
  - Determine coordinate transformation requirements to convert from the coordinate frame of the transmitting player to the coordinate frame of the data protocol used over WAN (e.g., geocentric coordinates for DIS PDUs) and to convert from the coordinate frame of the data protocol used over WAN to the coordinate frame of the receiving player.
  - Determine dead reckoning requirements. Determine if dead reckoning will be used at the transmitting node, as well as at the receiving node. Determine if second order or first order dead reckoning is required based on position and orientation accuracy requirements and estimated latencies (as discussed above).
  - Determine requirements for simulation interfaces to synchronize received data to receiving players. Stringent synchronization requirements may require that the receiving simulation interface dead reckon entity state data to the receiving simulation frame rate.
- Special-purpose interfaces (cost impact factor of rank #3 - see Appendix A).
  - Determine if special interfaces will be required to transfer synchronized data to SUT hardware. Such data may be required to permit proper real-time operation of weapons HWIL labs. For example, the JADS LFP ADS configuration required such an interface to link the shooter aircraft-generated targeting messages to the HWIL missile in real time. Development of such unique assets must be anticipated during the test concept development phase in order to prevent schedule slips.
- If HLA is to be implemented, interfaces will be required between all federates (e.g., player representations, range facilities, etc.) and the runtime infrastructure (RTI). See the DMSO HLA website for more details.

Operational issues and policies are also addressed and resolved including the following.

- Database requirements must be determined and documented in the ICD.
  - Determine requirements for a common terrain and features database, including resolution and level of detail.
  - Determine requirements for any other required common databases, such for radar cross sections.
  - Determine requirements for correlating data bases at distributed locations.
- Post-test data management requirements.
  - Determine the source and quantity of all data to be recorded at each recording location. A distributed test with numerous trials can generate a large volume of data at distributed locations. Without careful planning, key data may not be collected and/or transmitted to the analysis center, and data collected at the sites may not be in a useful form for centralized analysis. The DMAP must clearly identify (1) the data to be collected at each site, (2) on-site processing of the data, and (3) the data to be transmitted to the analysis center and data formats.
  - Determine data handling procedures for collecting and storing data from the distributed network. Determine if there are any special data handling requirements, such as for classified or sensitive data.

- An efficient method for retrieving the data to a central analysis facility is by use of the network links. After the test, data can be retrieved over the network by the use of the file transfer protocol (FTP) utility. This provides a timely, reliable, and secure data retrieval capability. (Efficient retrieval may require that the owners of the data at each site download their files into a central computer directory at the site before retrieval.)
- Use aggregated data quantities to determine the data storage requirements at each site, as well as storage at the central data analysis facility. The aggregated quantities are used to estimate the required data storage capacities. It is recommended that additional capacity be planned for (as a rule of thumb, plan for at least twice the estimated data quantities) since data quantities tend to grow as the test progresses.
- Using the aggregated data quantities, determine hardware requirements for data storage and handling (e.g., tape drives, compact disks, optical disks).

- Test control and monitoring requirements (cost impact factor of rank #14 - see Appendix A).
  - Develop the test control concept. This includes a determination of the central control location and the test coordination location at each distributed node/facility. See Appendix C for distributed test control considerations and guidelines.
  - Determine the techniques to be used for control of any live players.
    - For example, range policy may dictate the use of local air traffic controllers for live aircraft, so that control of each trial must be performed indirectly through them. (In other words, the setup of each trial would be initiated by the distributed test director who would request that the air traffic controllers vector the aircraft appropriately.)
    - If remote live player control is not precluded because of range safety considerations, determine the associated monitoring/communications requirements. If these requirements are rather complex and costly, the best choice for test control location may be at the range. During the early JADS LFP risk reduction missions it became apparent that when handling problems most of the discussions centered on experts and displays available only at the range. Therefore, in order to be part of the decision making process, the JADS test director had to be collocated with the Eglin Air Force Base range coordinator and the air traffic controllers.
  - Determine the display and monitoring requirements. This includes the requirements for monitoring the status/performance of any live players, simulation facilities, and the distributed network. Two-dimensional displays of the common synthetic battlespace are recommended at each node. This will greatly improve the situational awareness of the participants at each site. During JADS System Integration Test (SIT), the displays converted entity state data into symbols which were overlaid on a local area map. As a result, the test team members knew where and in what direction the aircraft were flying and if the missile simulation was active.
  - Determine the voice communications requirements for effective control and monitoring of the distributed test. Determine how many separate voice networks will be needed and how many individuals will be plugged into each network. Use these requirements to evaluate the adequacy of existing telephone systems to provide "loud and clear" communications. If existing telephone systems are judged to be inadequate, an option is to reserve a portion of the WAN bandwidth for voice communications.
    - Separate voice networks are advisable whenever certain groups in the test force only need to communicate among themselves. Examples are communications between the

player operators and the player controllers, communications between the test controller and facility/instrumentation operators, and communications among the decision makers at the sites. Limiting the personnel that can actively transmit on each network (using push-to-talk switches) results in clearer communications (others can listen on speakers).

- Existing telephone systems operated in a conference call mode usually can only accommodate a limited number of people with voice qualities that can vary significantly. Also, during conference calls over Defense Switched Network (DSN) phone lines, callers can be randomly disconnected.

3.4.3 Activity 4.3 - Implement Participant Modifications

According to the FEDEP model, the purpose of this activity is to implement participant modifications identified in previous activities. The input to this activity is the updated allocated participant requirements. The output is the modified participants.

The ADS test network should also be installed during this activity using the following steps (cost impact factor of rank #5 - see Appendix A).

- The WAN to be used to link the facilities is selected and procured.
  - This selection is based on a determination of whether a Department of Defense (DoD)-sponsored network can support the test requirements or if commercial leased lines must be used.
    - First the network requirements previously developed are consolidated, including bandwidth requirements, acceptable latency limits, aggregate data rates, availability/reliability requirements, and network management/control requirements.
    - Next the requirements are submitted to Headquarters, Defense Information Systems Agency, Defense Information Systems Network (DISN) Program Office for a determination of whether DISN common-user services (e.g., Defense Simulations Internet (DSI), Secret Internet Protocol Router Network (SIPRNET)) will support the requirements or if a waiver to policy is justified [Ref. 7]. Note that there is a minimum lead time of 180 days for acquiring common-user networks.
  - If a waiver to policy is justified, then commercial line lease rates are surveyed to determine if dedicated (full-time) leased lines are required or if on-demand leased lines will suffice (cost impact factor of rank #13 - see Appendix A). DoD agencies are required to contract for leased lines through the DISN Program Office.
    - This determination is usually based on test schedule and cost considerations. If at least weekly use of the network is anticipated during the ADS architecture integration and test and test execution phases, then it is generally more cost effective to contract for dedicated lines.
    - Once a decision has been made on dedicated versus on-demand lines, a contract for the leased lines must be processed. The contract processing time can be rather lengthy (up to six months), so that adequate lead time is needed to maintain the test schedule. Note that contracts for commercial leased lines can be somewhat expensive and can have difficult termination clauses. For example, the contract with American

Telephone and Telegraph (AT&T) to provide the T-1 line for the JADS LFP test cost $4448 per month with a minimum 12-month lease, required a 60-day notice to terminate the line, and had a $10,000 penalty for early termination of the contract.

- The network hardware to be used is selected, procured, and installed, including routers, channel service units (CSUs)/data service units (DSUs), multiplexes, encryption equipment, etc. (cost impact factor of rank #13 - see Appendix A).
  - It is advisable to use standard network equipment and to select the same brand of router hardware and software for all network nodes. JADS experience is that the lack of common router hardware and software can result in numerous interoperability problems. During the JADS linked simulators phase (LSP) test [Ref. 8], it was difficult to get the network to behave in a uniform fashion because of the many different types of interface hardware, routers, and interface software versions. Also, lack of common software resulted in the NIUs having numerous problems related to conversions, timing, central processor unit (CPU) speed, etc.
  - The router addressing scheme also needs to be determined (see Ref. 3 for details).
  - Acquisition of encryption equipment and keying materials requires a minimum of 90 days if the account is already established.
  - The use of a network test bed is recommended prior to installing and checking out the actual network. This allows an early test of the network design and its implementation, along with a check-out of the networking equipment. Using this approach, installation of the actual network becomes almost "plug and play," and the operators get early training and familiarization.
- The interfaces necessary for linking are built/procured in accordance with the requirements developed during Activity 4.2.
- Test control hardware and software are selected, procured, and installed based on the requirements developed in Activity 3.1 (cost impact factor of rank #14 - see Appendix A).
  - The selection criteria include both data and voice communications requirements.
  - Test control software includes that needed for player visualization at the test control center. If entity state data are to be transmitted to the center in the form of DIS PDUs, commercial and government off-the-shelf software are available for this purpose.
  - The test control center physical space requirements and layout are also determined.
- Network analysis/monitoring tools are selected, procured and/or developed, and installed. Considerations here are as follows (cost impact factor of rank #15 - see Appendix A).
  - The selection of tools depends on the desired extent of the analysis/monitoring. For example, diagnostic/troubleshooting tools are different from those for analyzing network performance.
  - Common practice is to monitor bandwidth utilization. In this case, tool selection is driven by such considerations as whether all links are to be monitored versus only some of the links and whether local area networks (LANs) will be monitored locally or from a central remote location. JADS used two network tools: Cabletron Systems, Inc., SPECTRUM® to monitor bandwidth utilization (more information at http://www.cabletron.com/spectrum/) and Silicon Graphics, Inc., NetVisualyzer™ to monitor packet rate and packet contents (more information at http://www.sgi.com).

- The JADS Electronic Warfare (EW) Test also used link health messages to monitor federate and communication link status. Each federate would broadcast its own link health status to all other federates at a rate of once per second. Details, including the message formats, are given in Reference 9.
- Before monitoring or collecting data from a LAN under the control of another organization, it will be necessary to obtain permission from the appropriate authority.

3.5 Step 5. Integrate and Test Architecture

According to the FEDEP model, the purpose of this step is to plan the test execution, establish all required interconnectivity between the nodes/players, and test the network prior to execution. The key activities for this step and the activity inputs and outputs are shown in Figure 6 [Ref. 1].

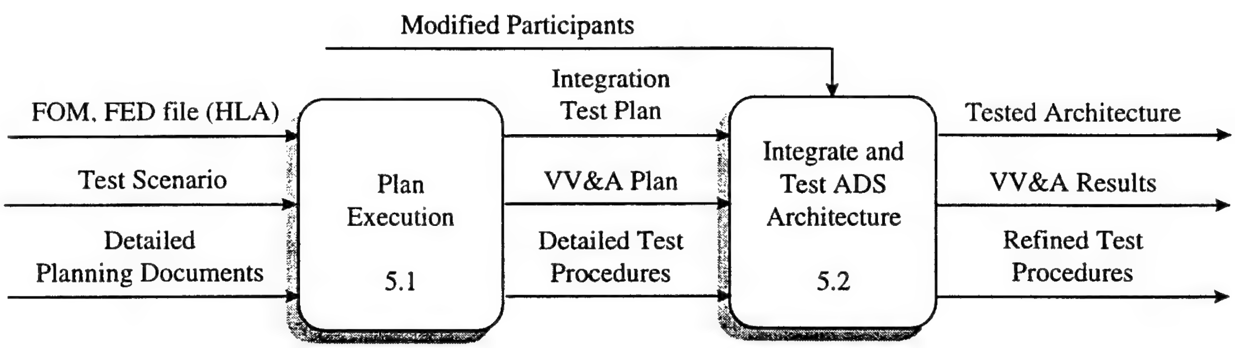


Figure 6. Integrate and Test Architecture

3.5.1 Activity 5.1 - Plan Execution

According to the FEDEP model, the purpose of this activity is to define and develop the full set of information required to support the distributed test execution. The inputs to this activity are the FOM and the FED file, if appropriate, the test scenario, and the detailed planning documents. The outputs are a refined and detailed integration test plan (cost impact factor of rank #8 - see Appendix A), VV&A plan (see Appendix B), and test procedures.

The test and VV&A plans (see Appendix B for VV&A considerations) should be refined, especially the integration test plan section (cost impact factor of rank #8 - see Appendix A). In refining the integration test plan, step-by-step systematic integration testing procedures need to be developed and should address the following.

- Procedures for verifying any simulation/range facility modifications or any new player representations in a systematic stand-alone fashion.
- Procedures for initially testing each WAN link separately. Testing should begin at the CSU/DSU level to make sure that communications work at the lowest level.
  - The complete simulation-to-simulation (or live player-to-simulation) connection should be tested for each link.

  - Coordinate transformations must be verified at each site and then reverified during end-to-end testing. Personnel who are subject matter experts in coordinate transformations must be assigned and readily available during this process.
  - The actual data protocols to be used during test execution should be used to verify message routing and check network loading.
  - Structured testing of the network must be performed prior to, and independent of, the linked testing times in order to verify transmission/reception rates, bandwidth utilization, latency, etc. "Pings" are useful to check for connectivity and loading problems.
- Procedures for testing each simulation-to-simulation connection with all network nodes connected. Network analysis/monitoring should be used to troubleshoot the network. Special test equipment (e.g., data loggers) and networking tools (e.g., SPECTRUM®, EtherPeek™) are useful for more rapidly isolating and determining the cause of network problems. Without these, trial and error becomes the normal troubleshooting mode which increases the resource requirements (time, schedule, cost, etc.).
- Procedures for testing the voice communications with all equipment and personnel as in the actual test.

Also, detailed test control procedures and a security test and evaluation plan should be developed. The test control procedures should include checklists covering activities for 24 hours prior, 4 hours prior, 1 hour prior, during the mission, and post-test. Examples can be found as appendices to the JADS test reports.[2] Existing stand-alone facility/range procedures serve as a starting point for developing the checklists. The system integrator uses these to develop new checklists which interleave the activities at each facility and include those unique to the distributed test environment.

3.5.2 Activity 5.2 - Integrate and Test ADS Architecture

This activity combines the separate FEDEP activities of "integrate federation" and "test federation" because of the close connection between the two. An iterative "test-fix-test" approach is recommended, so that the integration and test activities become closely interrelated. According to the FEDEP model, the purpose of these activities is to bring all the distributed test participants into a unifying operating environment and to test that they can all interoperate to the degree required to achieve the test objectives. The inputs to this activity are the detailed integration test plan, VV&A plan, and test procedures. The outputs are refined test procedures (to be used during test execution), VV&A results, and an ADS architecture that has been thoroughly tested and is ready for test execution.

Key testing steps during this activity include the following.

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[2] Reports for each phase of JADS testing may be found at the JADS website at http://www.jads.abq.com until March 2001. After that date, JADS reports will be available at HQ AFOTEC/HO, 8500 Gibson Blvd SE, Kirtland Air Force Base, New Mexico 87117-5558 and at the SAIC Technical Library, 2001 North Beauregard St. Suite 800, Alexandria, Virginia 22311.

- Perform compliance testing, as specified in the VV&A plan.
  - Test each facility/node individually to ensure that ADS capability and any required modifications (including software) have been correctly implemented. Specialized tools for reading and analyzing raw simulation/facility data are needed for this verification.
  - Acceptance testing of any software developed for the test is included in this step.
- Perform integration testing, as specified in the integration test plan.
  - Check out interfaces and facility modifications with linking between pairs of nodes.
  - Baseline the performance of the network with no loading from the simulations/players.
    - As discussed above, the use of a network test bed is recommended prior to installing and checking out the actual network.
    - If the use of a test bed is not possible, then the networking equipment should be tested individually first and should be preconfigured whenever possible.
  - Test performance of critical portions of the network under loading representative of test conditions to be used. Voice communications, as well as data processing and transmission, should be included in the loading conditions. This period should also be used to experiment with reliable versus best effort data transport modes in order to determine the optimum mix which balances lower latencies (using best effort) with lower data losses (using reliable). Useful testing tools for this process include the following:
    - Communications testers for bit error rate testing (e.g., Fireberd testers).
    - Protocol sniffers.
    - Simple Network Management Protocol (SNMP) tools are not critical but are nice to have.
    - Custom tools, such as displays driven by link health check messages.
  - Use an iterative "test-fix-test" approach, including replay of trials to diagnose problems and verify fixes. Trial replays are efficient and cost effective during this process and involve replaying input data recorded from the fully linked tests into critical interfaces. However, not all stand-alone facilities are designed to accept replay inputs and some modifications may be required. It may also be necessary to develop a special data player for this purpose.
    - Replays are also an excellent method for rehearsing and refining test procedures and for working out technical and procedural issues.
- Perform risk reduction missions. The purpose of these fully linked missions is to exercise all parts of the distributed test to ensure that they operate as intended. The early risk reduction missions are invaluable for identifying problems before the actual test. The later missions are used to verify fixes and serve as rehearsals for the formal test execution.
  - Execute the scenarios with the fully linked test execution configuration (using live players, if appropriate) and with all locations manned as in the actual test.
  - Include security certification, if required.
  - Evaluate test control and monitoring procedures, and modify the procedures, as appropriate, for the next risk reduction mission.
  - Execute data collection and analysis procedures, and modify the procedures, as appropriate, for the next risk reduction mission. Getting the data during the risk reduction missions is beneficial for developing and verifying analysis tools before the formal test

execution starts. During the JADS LFP test, this early exposure to the data gave the programmers and analysts time to read the raw data formats, choose among statistical packages, build real-time data display routines, make utilities to convert units, and rehearse analysis procedures.

- Perform validation, as specified in the VV&A plan.

3.6 Step 6. Execute Distributed Test and Analyze Results

According to the FEDEP model, the purpose of this step is to execute the distributed test, process the output data from the test execution, report results, and archive reusable test products. The key activities for this step and the activity inputs and outputs are shown in Figure 7 [Ref. 1].

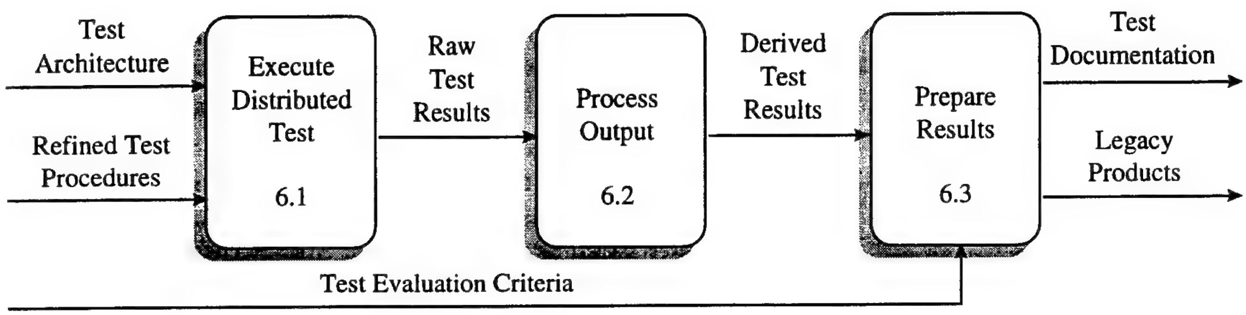

Figure 7. Execute Distributed Test and Analyze Results

3.6.1 Activity 6.1 - Execute Distributed Test

According to the FEDEP model, the purpose of this activity is to exercise all distributed test participants as an integrated whole to generate required outputs and thus achieve the stated test objectives. The inputs for this activity are the refined test procedures and tested ADS architecture from integration testing. The output is the raw test results.

The main function of this activity is to execute the test matrix detailed in the test plan. During execution, the following considerations apply:

- Pre- and post-test briefings are essential.
  - A premission briefing should be held 24 hours before each mission and is critical for coordinating the many network and test issues. The briefing agenda should include the test objectives, planned test matrix, personnel involved, telephone numbers/frequencies to use for test control, go/no go criteria, contingency plans in case of failures, instrumentation and data collection requirements, details on facility configurations, OPSEC, and the time and place of the debrief. Tactical equipment operators (e.g., air crews) should be involved and thoroughly briefed on the scenarios/profiles and their checklist items. If possible, the same operators should be used for each mission.
- Deploy test force personnel to the range/sites several hours prior to the mission to confirm that the preparations have been completed.

- Centralized test control/management and execution monitoring must be maintained, following detailed test control procedures and checklists. Go/no go criteria and contingency plans must be developed in advance.
  - Missions with live players require more contingency planning in order to quickly decide on alternatives. Good contingency planning will allow the test director to make rapid, well-informed decisions and get the most productive use out of remaining range time.
  - Detailed test cards should be used for each mission. The test cards should specify the profile(s) to be used for each trial and the configuration of each player. Back-up test cards should also be prepared for contingency purposes.
- Data are collected during execution to support both quick-look and detailed post-test analyses. The quick-look data are used by the analysts and SUT experts after each trial to ensure that the test objectives are being accomplished. Time must be allocated at the end of each test period for data logging, data archiving, data transfer, and facility reclassification (a minimum of two additional hours was needed during the JADS SIT).
- Strict attention must be given to maintaining the security posture of the ADS architecture during execution.
- Conduct an after-action review immediately after the test in order to gather important information from each facility, to formulate a course of action for correcting any problems, and to prepare for the next period of testing.

3.6.2 Activity 6.2 - Process Output

According to the FEDEP model, the purpose of this activity is to post-process (as necessary) the output collected during the test execution. The input to this activity is the raw test results from test execution. The output is derived test results.

The data are analyzed in accordance with the DMAP. The analysis should include the network performance, the SUT performance, and the impact of the network on the SUT performance. Statistical measures are applied, if appropriate, and other data reduction methods are used to transform the raw data into derived results. Error estimates due to inaccuracies in measurements and sampling are determined.

3.6.3 Activity 6.3 - Prepare Results

According to the FEDEP model, this activity has two purposes: (1) to evaluate the data analysis results in order to determine if all test objectives have been met, and (2) to identify legacy products and make them available to other programs. The input to this activity is the derived test results, along with the test evaluation criteria from Activity 2.3. The outputs are documented test results and legacy products.

Examples of legacy products include lessons learned, the final distributed architecture configuration, the distributed architecture performance analysis, and recommendations for future distributed test implementations. Detailed documentation of the distributed architecture configuration is important for potential replication of the configuration in future tests.

3.6.4 Return to Test Concept Development Process

If there are additional operational tasks relevant to the SUT, then the test planners need to return to Step 10 of the concept development process in Section 2.0 of this document. If there are no additional tasks, then the planning and execution process is complete.

4.0 Conclusion

This special report outlines the steps in planning and implementing ADS-based testing. The test concept development methodology guides the tester in making the decision on whether to implement ADS-based testing; the test planning and implementation methodology uses JADS lessons learned to illustrate the activities embodied in the FEDEP model.

Although the methodology steps are presented in a sequential fashion, experience has shown that many of the activities are actually cyclic with extensive feedback between activities and/or concurrent. Implementers should not enforce a strict waterfall approach to the steps given. Not only may variations in the order of the activities be appropriate, but it is frequently necessary to revisit previous activities as the distributed test requirements and design become more mature. The methodology given here must be tailored to each specific distributed test implementation.

5.0 References

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6.0 Acronyms and Definitions

AAA	anti-aircraft artillery
ABCCC	airborne battlefield command and control center
ABL	airborne laser
ADS	advanced distributed simulation
ANGLICO	air and naval gunfire liaison company
AOC	air operations center
AT&T	American Telephone and Telegraph
AWACS	Airborne Warning and Control System
CAS	close air support
CEA	circular error average
CEP	circular error probable
COI	critical operational issue
comjam	communications jamming
COMSEC	communications security
CONOPS	concept of operations
COTS	commercial-off-the-shelf
CPU	central processor unit
CSU	channel service unit
CTOC	corps tactical operations center
DIS	distributed interactive simulation
DISN	Defense Information Systems Network
DMAP	data management and analysis plan
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DSI	Defense Simulations Internet
DSM	digital system model
DSN	Defense Switched Network
DSU	data service unit
DT&E	developmental test and evaluation
ETE	JADS End-to-End Test
EW	electronic warfare; JADS Electronic Warfare Test
FAC	forward air controller
FAC-A	forward air controller-air
FED	federation execution data
FEDEP	federation development and execution process
FEPW	federation execution planners workbook
FO	forward observer
FOM	federation object model
FTP	file transfer protocol
GPS	global positioning system
HLA	high level architecture
HQ AFOTEC	Headquarters, Air Force Operational Test and Evaluation Center

HQ DISA	Headquarters, Defense Information Systems Agency
HWIL	hardware-in-the-loop
ICD	interface control document
IPT	integrated product team
IRIG	Inter-Range Instrumentation Group
JADS	Joint Advanced Distributed Simulation
Janus	interactive, computer-based simulation of combat operations
Joint STARS	Joint Surveillance Target Attack Radar System
LAN	local area network
LFP	live fly phase
LSP	linked simulators phase
MITL	man-in-the-loop
MOA	memorandum of agreement
MOE	measure of effectiveness
MOP	measure of performance
NIU	network interface unit
NTP	network time protocol
OML	Object Model Library
OPSEC	operations security
ORD	operational requirements document
OT&E	operational test and evaluation
PDU	protocol data unit
POC	point of contact
RCM	requirements correlation matrix
ROM	rough order of magnitude
RTI	runtime infrastructure
SAIC	Science Applications International Corporation
SAM	surface-to-air missile
SIPRNET	Secret Internet Protocol Router Network
SIT	JADS System Integration Test
SME	subject matter expert
SNMP	Simple Network Management Protocol
SOC	statement of capability
SOM	simulation object model
SPECTRUM®	a network analysis package developed by Cabletron Systems
STAR	system threat assessment report
SUT	system under test
T&E	test and evaluation
TACCSF	Theater Air Command and Control Simulation Facility, Kirtland AFB, New Mexico
TAOC	tactical air operations center
TCP	transmission control protocol
TDP	TSPI data processor
TOC	tactical operations center
TSPI	time-space-position information

UDP	user datagram protocol
VTC	video teleconference
V&V	verification and validation
VV&A	verification, validation, and accreditation
WAN	wide area network
WBS	work breakdown structure
WOC	wing operations center

Appendix A - Cost Factors for ADS-Based Testing

This table is intended to aid an estimator in creating a detailed cost estimate for an advanced distributed simulation (ADS)-based test and focuses on the unique aspects of an ADS-based test.

Impact Rank	Cost Factor	Risk to Estimate/Expected Impact to Total Cost	Recommended Estimator Response
1	Design and develop missing player representation*	High/High – Player representations can vary in fidelity and complexity from simple script-driven representations to high fidelity, man-in-the-loop simulators or live assets. Development of a new player representation can be the largest cost to an ADS test.	Request a bottom-up estimate from those most knowledgeable for each missing player. Special risk factors to estimate are stability of requirements, special instrumentation requirements, and verification, validation and accreditation (VV&A) requirements. Software models/script-driven representations may be estimated using standard parametric software models once a size estimate is made. Special risk factors to estimate are VV&A requirements and maturity of developer's software development process.
2	Modify existing player representation*	High/ High – Modifications can range from simple to extensive.	Request detailed estimate from simulation/range facility developer. Expect 10-15% over run from government organizations (based on the System Integration Test (SIT) experience). Special risk factors to estimate are stability of requirements, special instrumentation requirements, VV&A requirements, and maturity of developer's software development process.
3	Design and develop special-purpose interfaces	High/High – Special-purpose interfaces indicate high performance in some dimension is required and is critical to distributed test success.	Request bottom-up estimate from most knowledgeable source. Special risk factors to estimate are stability of requirements, special instrumentation requirements, VV&A requirements, maturity of hardware/protocol technology.

*Examples of player representations in an ADS-based test are digital simulations, hardware-in-the-loop (HWIL) labs, range facilities, and instrumented live assets.

Impact Rank	Cost Factor	Risk to Estimate/Expected Impact to Total Cost	Recommended Estimator Response
4	Latency	Medium/ Medium – Low transmission latency (<100 milliseconds) requires additional testing and development time to ensure architecture is tuned. Also increases ADS architecture integration and testing time. May require more expensive computers (multiprocessors) and network hardware. Increases the risk that simulation/range facility modification may be necessary. Increases the likelihood that ADS network instrumentation development is necessary.	Increase risk to integration schedule and budget for hardware upgrades. Investigate need for simulation/range facility modification and developing ADS network instrumentation. Unstable requirements add to the risks imposed by this factor.
5	Network architecture complexity	Medium/ Medium – Complexity is measurable in number of nodes, number of links, expected bandwidth used. High complexity in any of these requires additional architecture testing and development time to ensure architecture is tuned. Also increases integration and testing time. May require more expensive computers (multiprocessors) and network hardware. Increases the risk that player representation modification may be necessary. Increases the likelihood that ADS network instrumentation development is necessary.	Increase risk to integration schedule and budget for hardware upgrades. Investigate need for simulation/range facility modification and developing ADS network instrumentation. Unstable requirements add to the risks imposed by this factor.
6	Security	Medium/ Low – Primary risk is connecting at higher levels of security than facility/simulation normally operates. May require modifications to affected facilities. May increase operating costs of facilities. Other risks are in implementing multiple security levels in the same facility. This may require special hardware or procedures.	Increase risk to integration schedule and budget for hardware upgrades. Investigate need for federate modification and developing ADS instrumentation. Unstable requirements add to the risks imposed by this factor.
7	System engineering process/strong system integrator	Medium/ Medium – Poor history or weak systems engineering process will increase overall cost and schedule risk. Weak systems integration will increase design, development, and integration time. Also increases requirements volatility.	Increase risk to overall schedule and budget. Presence of poor systems engineering practices or weak systems integration will increase elements affected by requirements stability.

Impact Rank	Cost Factor	Risk to Estimate/Expected Impact to Total Cost	Recommended Estimator Response
8	Integration and testing	Medium/Medium – Integration and testing can be expected to reveal unforeseen problems which must be resolved before the distributed architecture is ready for the execution phase.	Do not rely on success-oriented integration schedule and budget. Plan on additional time and money for troubleshooting. Add additional risk reduction missions for testing anticipated fixes.
9	Maturity of requirements	Medium/ Medium – This is a reflection of the stability of the questions the distributed test is trying to answer. Indications of maturity are identification and documentation of measures and data elements that will be collected from the test and the existence of a federation object model (FOM), an interface control document (ICD), or a federation execution planners workbook (FEPW) for the distributed test.	Request an assessment of the maturity of the requirements from the lead engineer. Adjust risk to all elements affected by requirements stability according to the assessment.
10	Availability of player representations	Medium/ Medium – This element addresses the expected availability of each player during integration and execution. Simulation/range facilities that support more than one customer during the critical integration and execution periods increase the risk of schedule conflicts and delays. They also risk having to reconfigure to meet each customer's needs. Reconfiguration increases the potential for inducing problems during integration and further strain configuration management.	Ask for realistic assessment of each player's availability during the critical integration and execution periods. Increase integration and execution schedule risk for each simulation/ range facility supporting multiple customers.
11	Schedule	Medium/ Medium – This is a reflection of the time available to complete the test versus the initial estimate of the time needed to complete the test.	Review this list for factors that increase schedule risk.
12	Experience in ADS/ similarity to previous distributed tests	Medium/ Low – This is a correction factor to account for experience and design reuse.	Increase schedule and cost risk for no experience and little similarity to previous ADS tests. Do not correct for extensive ADS experience or complete reuse of previous ADS architecture since estimates should be more realistic.
13	Implement ADS network	Low/Low-High – This is the cost of acquiring and operating network links and standard wide area network (WAN)/local area network (LAN) equipment. This cost is not difficult to estimate, but recurring costs for long term tests could be large.	Commercial providers and communications support units can provide costs given the number and location of sites to be supported.

Impact Rank	Cost Factor	Risk to Estimate/Expected Impact to Total Cost	Recommended Estimator Response
14	Design and develop test control center	Low/Low – This is the cost of acquiring and implementing a test control center. This cost is not difficult to estimate after the test control concept has been developed.	The lead engineer working with communications support personnel should be able to develop a control concept and associated parts list.
15	Implement network instrumentation	Low/Low – This is the cost of acquiring and implementing instrumentation to measure latency, bandwidth, link health, and other ADS network measures. Player instrumentation is included in other elements.	The lead engineer working with communications support personnel should be able to identify instrumentation requirements and develop an associated parts list.
16	Implement configuration management system	Low/Low – This element acknowledges the increased demands on configuration management of ADS over traditional testing. Poor configuration management will increase the integration schedule.	Increase integration schedule risk for players that do not have demonstrated strong configuration management practices.

Appendix B – Guide to the VV&A of an ADS-Enhanced Test Environment

The verification, validation and accreditation (VV&A) of an advanced distributed simulation (ADS)-enhanced test environment should proceed hand in hand with the design and development of the environment. This guide to the VV&A of an ADS-enhanced test environment will associate the appropriate VV&A activities with the activities contained in the ADS-based test planning and implementation process. More details on the VV&A methodology for ADS-based tests are available in a JADS special report.[3]

The High Level Architecture (HLA) Federation Development and Execution Process (FEDEP) model lists six steps needed to develop and execute an ADS-based test. It should be noted here that these six steps might involve loop-backs as the development and execution of the test proceeds. When a loop-back occurs, the corresponding verification and validation (V&V) will be repeated if changes are made to the design or execution of the test. The six steps, as listed in Section 3.0 of the main report, are

- Step 1: Define Distributed Test Objectives
- Step 2: Develop Conceptual Model
- Step 3: Design Distributed Test
- Step 4: Develop Distributed Test
- Step 5: Integrate and Test Architecture
- Step 6: Execute Distributed Test and Analyze Results

An ADS-based test has the requirement that the ADS-enhanced test environment and its components must be accredited before the test may be executed. Since the accreditation authority is in the test development and execution chain, a step needs to be added to the model between Step 5 and Step 6. Step 5a becomes "accredit ADS-enhanced test environment."

B.1 VV&A Considerations for Step 1 (Define Distributed Test Objectives)

Early in this step the test manager should appoint a V&V lead, and if the test manager is the accreditation authority, an accreditation team lead. If not the accreditation authority, ask the accreditation authority to appoint an accreditation team lead to be a member of the integrated product team (IPT) for the test.

As the set of objectives for the test matures, the accreditation team lead and the V&V lead should discuss accreditation requirements and how the V&V will be conducted. Broad requirements and acceptability criteria should be arrived at so that the V&V plan can be developed. Issues such as V&V products required by the accreditation team, independent V&V versus in-house V&V, and the role of contractors, if any, in the V&V need to be agreed upon and documented. It

[3] MAJ Michael Roane and Gary Marchand. *JADS Special Report on Verification, Validation and Accreditation of Distributed Tests*, available from the Download Area of the JADS web site: http://www.jads.abq.com/html/jads/techpprs.htm.

is also helpful for them to identify subject matter experts (SMEs), to be used throughout the test and V&V, who are acceptable to both the test manager and the accreditation authority.

The accreditation team lead will also need to ask the accreditation authority if an accreditation team from within the accrediting organization (Joint Advanced Distributed Simulation [JADS] System Integration Test [SIT] and Electronic Warfare [EW] Test) or a team composed of SME from outside the organization (JADS End-to-End [ETE0 Test) is wanted. Once this is accomplished, write an accreditation plan describing the composition of the accreditation team, the accreditation objectives, and the accreditation requirements or acceptability criteria.

It is at this point that the overall V&V plan describing the tailored process that will be used by the V&V team and the roles of the members of the IPT should be written. This plan will be nonspecific with regard to actual V&V activities as the actual simulations, nodes, requirements, and acceptability criteria for the ADS-enhanced test environment have yet to be determined. It will match major V&V events with major test events and describe the specific V&V events that will be conducted to meet the previously agreed upon broad acceptability criteria. It will also identify future V&V plans to be developed that will be specific in nature. This plan will be used to cost the V&V process.

It will also describe in some detail how the conceptual model will be validated, as this validation will occur prior to firm requirements being developed. Finally, it must identify the types of data required to evaluate how well the ADS-enhanced test environment meets the test objectives. This must be done at this step so that the test designer can make provisions for the collection of these data in the test design. This plan must be approved by the test manager, after review by the test designer, schedule personnel, resource personnel, and the accreditation authority or a representative.

Early validation of the conceptual model may begin during this step as SMEs are employed to review the federation objectives, approach, and technologies. The efforts of these SMEs should be documented for future use. Any work that tries to determine how well the ADS-enhanced test environment will represent the real environment should be considered as conceptual model validation.

B.2 VV&A Considerations for Step 2 (Develop Conceptual Model)

This step is composed of three activities that are very important to the VV&A of an ADS-enhanced test environment.

B2.1 Activity 2.1 – Develop Scenario

The basis for the V&V of the scenario(s) to be used in the test must be established here. The V&V team must work closely with the scenario developers documenting data sources, doctrinal sources, and fidelity requirements. The requirements for the V&V of the scenario should have been identified in the V&V plan developed during the previous step, to include the accrediting authority for the scenario.

B2.2 Activity 2.2 – Perform Conceptual Analysis

It is at this point that the distinction between test team members and V&V team members becomes fuzzy. The purpose of this activity, for the test team members, is to ensure that the conceptual model maps to the objectives, scenario, doctrine and tactics, and fidelity requirements of the test. In other words, they want to determine how well the federation represents the real-world test environment and is the representation adequate. They do this in order to reduce risk prior to proceeding with the development of the federation. The V&V team wants to do the same thing. The two teams, if they are different people, should work together within the IPT structure to ensure that this activity provides the required degree of risk reduction to the test manager, as this is its primary purpose.

With respect to the accreditation of the ADS-enhanced test environment, the validation of the conceptual model is a freebie. The results will be overshadowed by the validation of the constructed federation and the accreditation decision will be based upon the performance of the federation not a conceptual model. As stated above, conceptual validation is conducted in order to reduce risk.

B2.3 Activity 2.3 – Develop Distributed Test Requirements

This is probably the most important activity, with respect to V&V, in the test planning methodology. Requirements, to the person conducting V&V, are like specifications to a person building a system. They dictate what the federation and its federates have to do to satisfy the test objectives and measures. As stated in the test planning methodology, they fall into several broad categories. These categories are fidelity requirements, interaction requirements, latency requirements, data reliability requirements, and data analysis requirements. All require V&V effort to determine how well the federation and its federates meet the requirements.

It is critical that the V&V team be a part of the IPT and participate in the development of the requirements. They will be able to offer valuable insights as to what is measurable quantitatively and what must be measured qualitatively. It is equally important to have the accreditation team lead present because it will be the responsibility of the team lead, working with the test director and the accreditation authority, to develop the acceptability criteria.

If the requirements state what the federation and its federates should do, the acceptability criteria state the minimum acceptable performance of the federation and its federates. Ideally, the tester would like for any simulation of a system, or process, to be perfect. Practically, close is often good enough. The acceptability criteria define close. If the federation and its federates fail to meet an acceptability criteria, the accreditation team has the option of recommending that the federation be modified to meet the criteria or that the test proceed at the observed level of performance.

Once the requirements and acceptability criteria are identified, the detailed V&V plan(s) may be developed stating the specific V&V activities to be performed during the design, development,

integration and testing of the federation. These plans must be approved by the test manager, after review by the test designer, schedule personnel, resource personnel, and the accreditation team.

B3 VV&A Considerations for Step 3 (Design Distributed Test)

The V&V team will need to work closely with the designer during this phase as it functions as a quality control team for the test manager. Its responsibility is to verify that HLA federation and federate rules have been followed, where applicable, and that the federation and federates conforms to the object model template. The team should also document any deviations from the HLA rules and the reason why the deviations were required.

The V&V team will also verify that the detailed design will meet the acceptability criteria arrived at during the last step and that the objectives of the test will be met by the proposed design. All or most of these tasks will also be conducted by the design team. The V&V team provides a second set of eyes, with a slightly different perspective, to ensure that the design is adequate and to reduce risk within the test. The use of modeling tools, to model the federation and its federates, is recommended as a V&V or design tool during this step.

Finally, the V&V team will verify that adequate provisions are made in the design for the collection of data to V&V the final federation as assembled.

B.4 VV&A Considerations for Step 4 (Develop Distributed Test)

This step is a continuation of the previous step and the V&V effort will be directed toward reducing risk. As federates are modified, they will be tested to ensure they meet requirements and that they continue to be HLA compliant.

The major emphasis at this point should be on ensuring that the federation will satisfy the test requirements and objectives and less on standards compliance. The purpose of V&V is not to act as a standards policeman. Given the choice of a successful test meeting all requirements and objectives or blind adherence to a standard, most test managers will decide on the former. Deviations from standards should be documented and reported to the standards authority along with the "fixes" employed to make the test environment work.

As they are identified, components of the federation, to include hardware items, may be procured and tested for HLA compliance and functionality. Items such as routers, crypto devices, and leased communication lines may also be tested and characterized within the federation configuration. It is recommended that a test bed federation with dummy federates be established using all the actual hardware components before moving to the next step. The dummy federates receive and publish data in the same manner and at the same rate as the actual federates are expected to perform. This allows the test bed to experience the same interactions and data flow as the actual federation. Interactions and data flow may be determined from the model of the federation recommended in the previous step.

Using the test bed, hardware upper limits can be established for data flow within the federation, and the effects of changes to the architecture and data flow can be easily observed. Proper documentation is essential at this point, especially if changes are made to the architecture that deviates from the HLA standard.

B.5 VV&A Considerations for Step 5 (Integrate and Test Architecture)

Up to this point, the purpose of the V&V conducted was to reduce risk. The V&V conducted during this step will be used to convince the accreditation team and the accrediting authority that the ADS-enhanced test environment, or federation if HLA is used, meets the acceptance criteria or at least performs well enough to proceed with the test.

V&V activities must be coordinated with the integration and functionality activities conducted by the test team. Ideally, no additional resource requirements because of V&V will be placed on this step. The purpose of this step is to assemble the ADS-enhanced test environment and determine how well it functions. Functionality is measured in terms of how well does the environment meet its requirements. V&V also need to determine and document how well the environment functions. Whether it is called functionality testing or V&V is immaterial, both have the same objective.

Compliance issues should have already been answered and documented. That is why the use of the previously mentioned test bed is recommended. Deviations from HLA standards, in order to make the ADS-enhanced test environment meet requirements, will be more readily accepted than an HLA-compliant test environment that does not meet requirements.

Occasionally, a system or system of systems will be tested that is so complex that the ADS-enhanced test environment only exists during actual test events. An example is the JADS ETE Test conducted by JADS that contained an aircraft flying at 35,000 feet over Texas. Because these events are often costly in terms of time and resources, the test manager is reluctant to allocate one of these events to V&V. Sufficient integration and functionality testing can take place on the ground to satisfy the test manager that the ADS-enhanced test environment has a high chance of success during an actual test trial. V&V can also be conducted of the almost real ADS-enhanced test environment to answer how well the environment meets the test requirements. However, if the test environment exists only during the test, the V&V conducted are again risk reduction events.

B.5.1 Step 5a – Accredit ADS-Enhanced Test Environment

This is probably the easiest step in the process, provided the previous VV&A activities have been performed as suggested. You normally do not arrive at this point in the process unless the ADS-enhanced test environment is performing well enough to satisfy the acceptability criteria established by the accreditation authority. In addition, if you have fully involved the accreditation team in the planning and conducting of the V&V events, they already know how well the ADS-enhanced test environment meets the acceptability criteria. This is especially true

if you provide them with the supporting documentation as it is produced, rather than dumping all of it on them just prior to the accreditation meeting.

Obviously, if the actual test environment has not been verified and validated, as described in the last step, the accreditation of the actual test environment cannot take place until after the test event(s) have been conducted. The accreditation will be based on the actual test performance of the environment and will confirm that the data collected during the test are valid. The accreditation team should meet prior to the test and consider the V&V conducted during the integration and testing of the "near" actual test environment. They can still recommend proceeding to test with the stipulation that the final accreditation will not occur until after the test.

If this is not acceptable, the accreditation authority will have to be willing to accept the allocation of the first test event to V&V with the understanding that if the test environment is subsequently accredited, the data collected during the V&V are valid SUT data.

B.6 VV&A Considerations for Step 6 (Execute Distributed Test and Analyze Results)

Why V&V after the ADS-enhanced test environment has already been accredited? Well, simply put, most ADS-enhanced test environments are so complicated that the only way you can tell they are functioning correctly is to repeat some of the V&V activities during the test event. In order to prove that you have collected valid test data, you must establish that the ADS-enhanced test environment was meeting its requirements.

Appendix C - Test Control Structures for Distributed Testing

C.1 Test Control Mechanism

A test control mechanism is a critical element of every test event. Control is exercised by a test director who is the person responsible for test execution. In live testing, control is often exercised from a range control facility. In developmental test and evaluation (DT&E), control may be exercised from a laboratory control center. Regardless of the type of testing, a workable test control capability is a fundamental requirement for each and every test event. Distributed test events are no exception to the rule, they also require a test control mechanism, but the distributed environment demands some differences in approach.

C.2 Local Control Mechanisms

In a distributed test architecture, participating facilities are scattered. The facilities may be represented in any of the three forms of advanced distributed simulation (ADS): live, virtual, or constructive. The facilities may include hardware-in-the-loop (HWIL), man-in-the-loop (MITL), digital system models (DSMs), simulators, or simulations, or combinations of such capabilities and assets.

At each node in the distributed architecture are people who are expert in the maintenance and operation of the capabilities of that node. There are also hardware and software capabilities to observe and report on the operations of local devices. At each node there needs to be a local control mechanism with a single person responsible for test support operations. The control mechanism incorporates a level of local decision authority appropriate to the expertise at the node. Only the local experts know the resident systems characteristics and behaviors well enough to make on-the-spot judgments about status, performance, and risk. When live players are involved at a node, then it is clear that safety-related decision making must take place at the node.

Local control mechanisms should be designed perform two functions. The first is to provide the ability to start, stop, or hold local activities in response to situations where safety, damage prevention, security, or other kinds of critical elements are involved. The second is to provide continuous and timely status reporting to a central agency responsible for overall test control. Some of the hardware and software necessary to support reporting will not be a part of the local system. The test program supported will have to provide, install, and sometimes operate, the equipment and programs required to interface with the distributed status and control system. The equipment can range from new communications lines to routers, switches, data loggers, and network interface units.

C.3 Central Control Mechanism

As with traditional test control, distributed test control is exercised by a test director. Like a traditional counterpart, the distributed test director is responsible for test execution. Unlike a traditional counterpart however, the distributed test director has less hands-on control of the environment because the elements of the environment are geographically dispersed.

It is both sensible and necessary that any node retain the authority to start or stop local operations in response to circumstances at its site. It is the test director, however, who decides whether to stop or modify ongoing test activity. As an example, it is possible that a breakdown at a single test node may not be fatal to continued testing -- it may force a change in test event type but not force a halt to testing. It is the central authority, the test director, who has to make test start, test stop, and test modification decisions relevant to the test event.

The timely and continuous status reporting from the local nodes is a critical underpinning of the central control mechanism. Much of the reporting can be automated. Commercial-off-the-shelf (COTS) software is available to monitor the condition of each piece of hardware in the system, data flow in each leg of the architecture, and the real-time values of error sources such as latency.

The central control facility must have the display and communications capabilities to know total system health in real time. Total system health includes not only the status of the real, virtual, and constructive players, but the data processing and collection system, and the system synchronization mechanism.

C4 Blending Local and Central Control Mechanisms

The challenge in constructing a test control mechanism for a distributed test lies in the proper mix of central and local control. Many test and evaluation (T&E) organizations are used to having absolute control over their own resources, and they tend to bridle at the notion that control may reside outside their bailiwick. The ranges are particularly sensitive to what they see as intrusions over their control of live assets.

If only one range with live players is incorporated into an architecture, then it is technically feasible (although it may not be desirable for other reasons) to locate the test control center within the range control facility. If more than one range is involved, then there have to be some accommodations. The guiding rule for blending areas of control is "don't do anything stupid."

The ranges have the mechanisms to control operations at their locations, so they should control operations. That includes clearing range activity, controlling actions on the range, making safety and weather decisions, aborting missions, and the like. Having said that, a range is not in a position to know the real-time status of every item in a distributed architecture. Only the test control center, wherever it is located, has what might be termed a global picture. The test control center controls the test and that includes starting the test, terminating the test, or directing modifications to ongoing test activities. The direction of modifications -- such things as

changing routes or timing, altering engagements, etc., is an area where there is potentially a direct interface with the ranges. The implementation of the test director's modifications may very well have to be implemented at the sites where there are live players. To put it another way, direction to modify "operations" may have to be passed to the local controlling agency (range control center, for example) for execution rather than directly to the players.

An area of concern within the control function is configuration management. There should be a clear understanding among all parties that configuration control is a function of the test director and that local changes in configuration require the test director's approval.

C.5 Designing a Test Control Mechanism:

The preceding paragraphs in this section were intended to describe the conceptual view of test control within a distributed architecture. From a process point of view, the construction of a test control mechanism for a distributed test is requirements driven, and the requirements are test specific.

The test planning and implementation methodology described in Section 3 of this document provides the blueprint for a given test or test event. Once the test is defined to a level where the objectives, the measures, and the supporting data elements are known, then Step 1 of test control design can be initiated.

C.5.1 Step 1. Laying Out the Instrumentation

When all the data elements are identified in the test plan, it is possible to lay out the instrumentation and data collection plans. The instrumentation and data collection structure are important to the control design because the test control center must be capable of monitoring the status of those elements in detail. The test director must ensure that the entire instrumentation and data collection system are functional before directing the start of testing. If a piece of instrumentation or data collection equipment goes down, it may be necessary to stop a test in progress. In many cases, the instrumentation and data collection system will be imbedded in existing local area networks (LANs) at the various nodes. In some cases it may be necessary to create new LANs.

C.5.2 Step 2. Laying Out the Wide Area Network (WAN)

In Step 1, the information about the data elements, their points of origin, and the technical characteristics of the data streams are developed. That information defines the basic connectivity required in terms of number of nodes, data types, and bandwidth. In effect, the information defines the outline of the WAN. (See Sections 3.3.1 and 3.3.2 for specific methodology on network design and development.) The bandwidth requirements identified in this phase are tentative. There will be additional bandwidth required to support redundancy (if needed) and control functions.

C.5.3 Step 3. Laying Out the Test Control Center

When there is a good understanding of the network layout, it is possible to initiate design of a test control center. The displays must accommodate representation of instrumentation and data flow throughout the distributed architecture. Network monitoring and recording capabilities must be identified. Voice and video communications links must be established to meet control needs. Logging, recording, storage, and playback devices must be identified. Network synchronization capability needs to be addressed. Quick-look analysis capabilities need to be defined and supporting equipment identified. When the technical capabilities and the supporting equipment are well defined, then manning and space needs can be addressed. Step 3 defines the requirements for the test control center.

C.5.4 Step 4. Choosing a Location for the Test Control Center

In theory, a test control center could reside anywhere in a linked architecture. In practice, cost will weigh heavily in the decision about location. If the test director owns or has access to a range control facility, such a site may be an ideal location for a test control center. Range control facilities have most of the control functions required for distributed testing already. They have displays, processing power, voice (and in some cases video) communications, and some data recording and storage capability. When the requirements identified in Step 3 are overlaid on the capabilities of an existing control facility, then the necessary modifications can be identified and costed, and that data can be weighed in the site selection process.

C.5.5 Step 5. Integrating Local Control Nodes with the Test Control Center

Once a test control site is selected, integration of the entire distributed architecture can begin. Facilities participating in the distributed test are providing access to resources they operate on a routine basis. Within their own facilities, or sometimes their LANs, they have their own control mechanisms. The modes of communications among the test control center and the control centers at the nodes have to be addressed on a case-by-case basis. Is voice a requirement? Do I need an open line? How about video? When such questions are answered, then the impact of the solutions needs to be fed back into the WAN and LAN design requirements.

Aside from the technical issues of integration, there are bureaucratic issues to contend with. It may be desirable to establish memoranda of understanding or agreement between the test director and the supporting facilities to lay out the specifics of control sharing. In the execution of this process step, it is also advisable to address the need for assigning test force personnel to each of the nodes. If there are such needs, then the agreements need to address them.

C.5.6 Step 6. Documenting Control Processes and Procedures

Once the control mechanism architecture is defined, it is possible to move on to the final step in the process. Complex tests are like complex weapons systems in at least one regard. Checklists and procedures are required. Rules of engagement have to be documented. Start-up procedures

need to be developed and implemented. Players in the control process need to be specifically identified and their responsibilities defined and documented. Emergency procedures have to be defined. The list goes on. Each test will have different sets of procedures, but there is a common thread in all tests. Procedures must be developed, documented, and rehearsed. As changes occur, and they will, the changes must be captured in the documentation.

C.6 Summary

This part of the document doesn't contain great detail. Individual tests have individual control mechanism needs. The common characteristic of all distributed tests is a dispersed player set. That dispersion forces the test planner to develop a control mechanism which provides a sensible blend of local and central control.